Building Zero Net Energy (ZNE) Communities
Passive House Design & Smart Home Technology
Web-based Programmable Automated Controls
Model Home Technology Showcase

Providing a Paradigm Shift in Energy Efficiency, Quality & Affordability
via Insulated Concrete Form Technology, Systems Architecture,
and State-of-the-Art Construction Management

Smart Home Technology & Automation

- Energy & Building Code Compliance with IECC 2012
- State-of-the-Art Insulated Concrete Form (ICF) Technology using Structural Lightweight Concrete, Steel Fiber Reinforcement and Self-Consolidating – Capitalizing on the High Thermal Mass of Concrete while Reducing Construction Labor by 50%.
- Integrated Solar Thermal, 100% Variable ECM Water to Water GSHP, Desuperheater, and 96% Efficient ERV for provision of 1st stage Radiant Floors and 2nd stage Fan-coil Heating & Cooling, Domestic Hot Water, and Solar Thermal Energy Storage System (the heat capacity of water is 3,467 fold greater than air, and water pumps are 90% more energy efficient than blowers/fans)
- Web-based Programmable Automated Controls (PAC) for Home Security, Home Theater, Sprinklers, and Integrated HVAC Renewable Energy Systems including Ground to Air Heat Exchangers & Cool Air Flush
- Up to 95% Reduction in Peak Heating & Cooling Capacity
- Over 50% Reduction in Energy Consumption via Safe Hybrid AC-DC Power Distribution System including AC-DC Rectifier or Bidirectional Gateway, Power Server Module, Solar PV, Solar Thermal, 97% Efficient MPPT DC-DC converter, Battery Storage, PoE and USB PD technologies

Zero Net Energy - Passive House Model Home

- Ultra-efficient DC Powered LED Lighting, AC & DC Smart Appliances, Consumer Electronics, and EV Charging Station
- Up to R-12 (U-0.0833) High Performance Windows (four layer twin suspended film IGUs with 80-95% krypton gap fills, coated stainless steel spacers, strategic low-e coatings), aluminum clad exterior, thermal break with wood interior, and automated exterior shades providing an additional air-filled gap for optimizing thermal efficiency at night (while strategically enhancing solar radiation and provision of natural lighting via southern orientation during the day)
- High Performance Glass Doors & R-14 Insulated Entry Doors (with state-of-the-art foam installation to eliminate thermal bridging) & Storm Doors
- CAT-6 10GBASE-T Ethernet Wiring + Wireless Home Area Network & Home Cloud
- Smart Home Sensors, AC & DC Smart Plug Technology & Energy Management System
- Superior Technology & Quality Construction at Affordable Pricing via 50% Reduction in Labor, Direct Purchasing & Sweat Equity Programs
- Energy Tax Credits & Energy Efficient Mortgages (EEM)

BEopt Modeling & Simulation Software

- Developed by DOE & NREL, it is free to the public for evaluating technologies and associated economics via modified internal rate of return (MIRR) of less than 7 years.
- The primary objective is to achieve 85-95% of Zero Net Energy using basic passive house design, then bridge the gap using solar PV/T technologies while staying within a targeted budget for a specific homeowner. This approach includes adding substantial value via full basements and finished attics.
- This can be accomplished beginning with a tight concrete envelope (ACH@50 <0.1), relatively inexpensive nominal R-28 ICF walls, a nominal R-6 exterior cultured stone (assembly R-value well over 200 using parallel path calculation described in ASHRAE Fundamentals Handbook) installed by the homeowner, R-60 ICF panel vaulted ceiling (assembly R-value near 120), high performance double pane windows, and a simple yet efficient integrated HVAC-ERV system and controls.

Achieving in Excess of 150ft^2/man hour

- Systems approach to architectural design and engineering
- Direct purchasing of materials
- Innovative ICF technologies
  - Hybrid big block ICF technology that requires no-assembly on site via hinged webbing, four-way reversible, corner and T-blocks
  - FastFooting monopour system which eliminates need for using and removing conventional footing forms
  - Development of low-cost structural lightweight concrete that is self-consolidating with plasticizer and steel fiber admixes that reduce need for conventional rebar
  - Innovative bracing and shoring
  - ICF floors and vaulted ceiling system using T-Beams
- State-of-the-art construction management
  - Electrical, plumbing and HVAC installed by experienced ICF crews

ICF Hybrid Big Block-Panel Technology

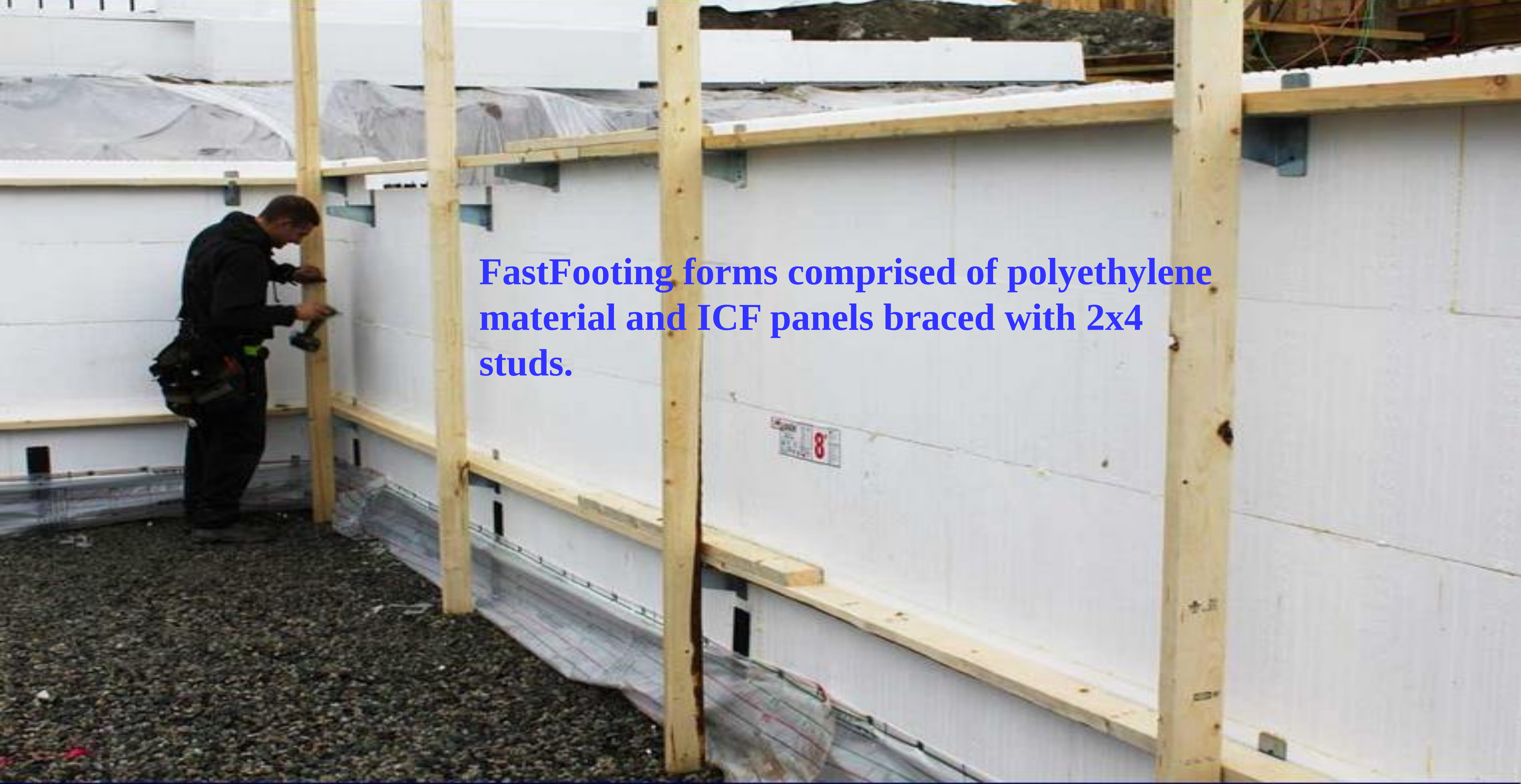
- Produced from house plans in the shop and shipped to the building site.
- Substantially reduces labor required on the building site.
- ICF panels are integrated with polyethylene (FastFooting) technology.
- When utilized with plasticizer and steel fiber admixes, the need for conventional rebar is substantially reduced.
- Conventional rebar is only required for reinforcing lentils, T-Beams, and connecting cold joints.

ICF Blocks Converted into Panels at the Shop

ICF Hybrid Big Block-Panel Technology

Full wall height ICF panel with FastFooting technology. Ready to be placed, strapped, braced, and poured using self- consolidating concrete and steel fiber admixes at the building site.

Strapping ICF Panels before Pouring Concrete



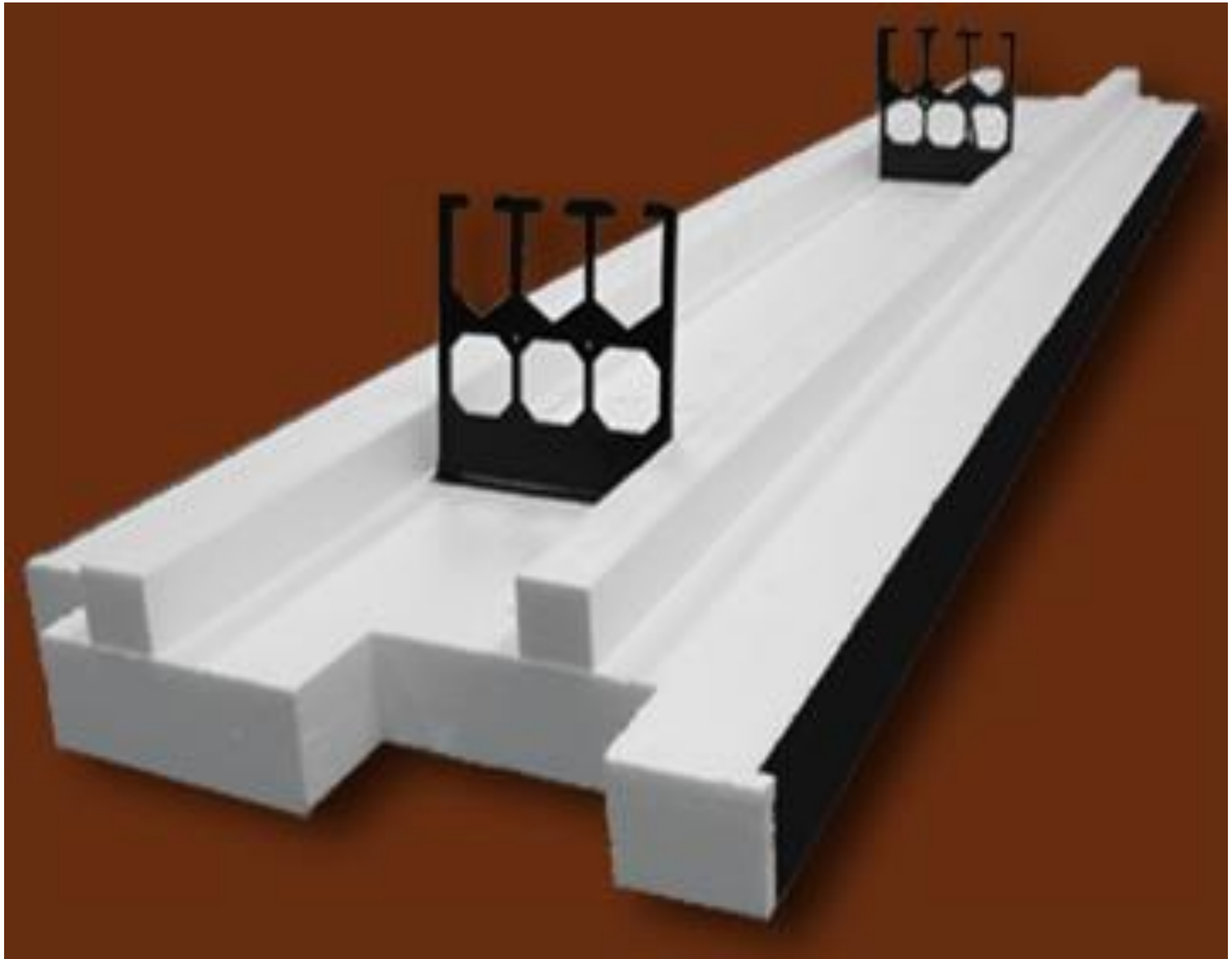
FastFooting forms comprised of polyethylene material and ICF panels braced with 2x4 studs.

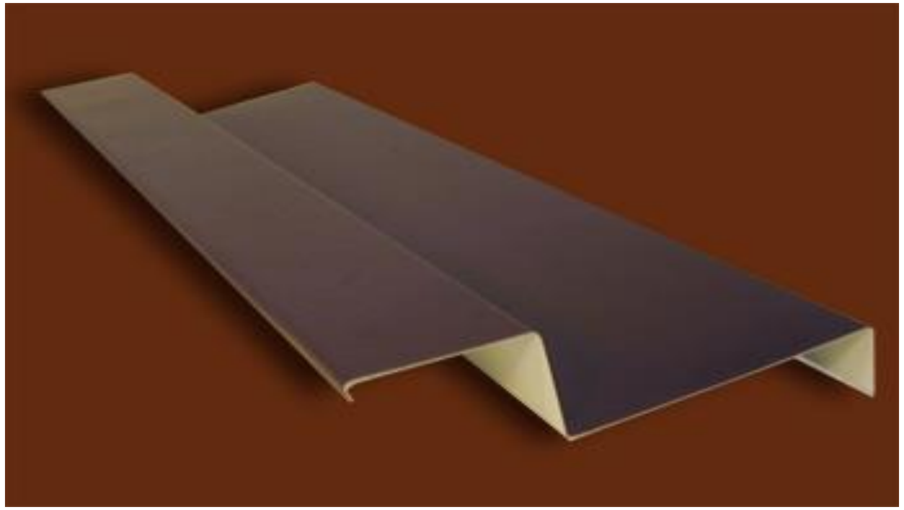
Two levels of components have now been installed. The Zont bracing is attached to align the wall and fix into exact location with stakes at the base of each vertical strongback.

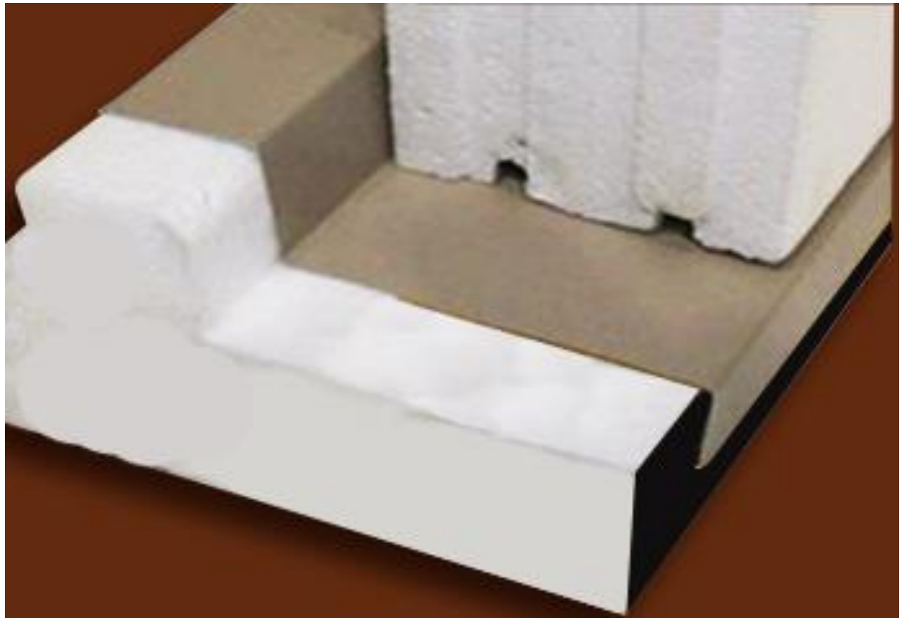
Polystyrene Plastic & EPS Window & Door Bucks

- The Molded Gorilla Buck provides R-4.1/inch for use with ICF construction. The design allows water to drain to the exterior of the building and allows for the flashing of windows and doors to extend back to the concrete cavity.
- At the heart of the molded buck is a recycled polystyrene plastic which bonds to the EPS foam, providing for a strong buck plank.
- The foam is molded around the continuous embedded plastic ladder with exposed edge plastic for solid mounting of windows and other trim elements. Bonding the ladder and buck to concrete are 3 rebar holder-anchors that fold into position.

Polystyrene Plastic & EPS Foam Construction

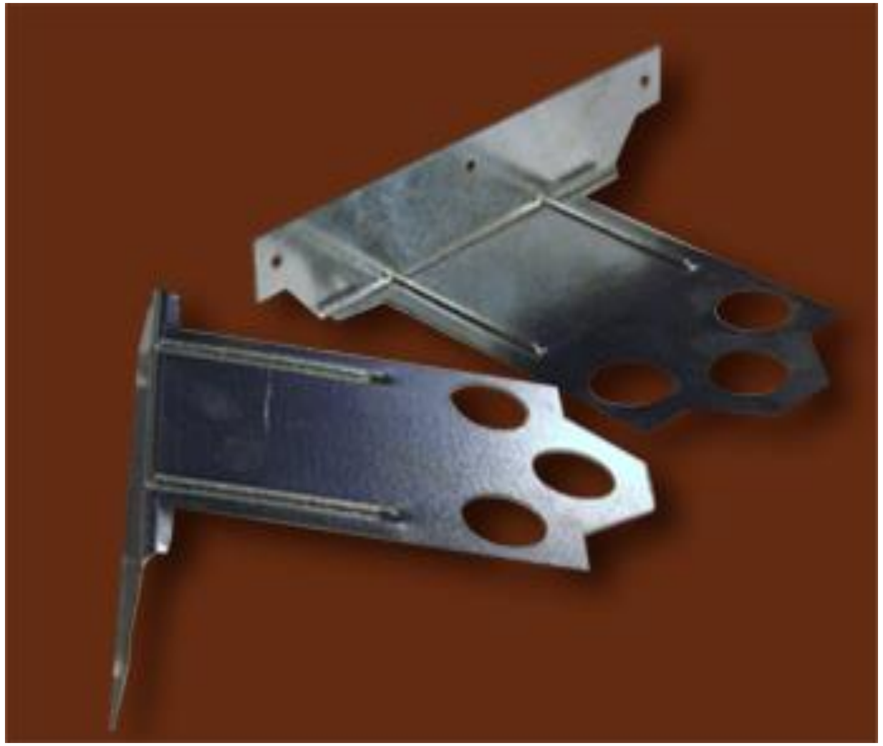






Rebar Brackets for Window & Door Bucks

A quick horizontal cut with a circular saw allows a Gorilla rebar bracket to be inserted through the span in the window or door buck. A choice of hole sizes allows for aligning most standard rebar sizes during the pour. This enables structural uniformity to be maintained, while the galvanized non-corrosive finish assures maintaining long term structural integrity.



Gorilla Buck Design Features

- Allows water to drain to the exterior of the building
- Solid and continuous edge plastic for a stronger and more rigid buck plank
- 100% recycled plastic components
- Polystyrene plastic bonds and fuses to the EPS foam during manufacturing
- Notched plank ends allows for better moisture control at buck frame corners to keep water out of the building
- Fold up rebar holders that allow perfect placement of reinforcement bars around doors and windows and also provides and mechanical bond of the buck to concrete
- 1 3/8” wide face fastening straps on 8” centers for center mounting windows and for fastening finishes easily.

Passive House Design

- Passive house design refers to a house or building that largely heats and cools itself.
- The house or building actually doesn’t consume much energy in the form of oil, gas, electricity, or other conventional means, but uses natural resources including geothermal and solar energy to provide virtually all of the energy needed to be self-sufficient. Essentially, geothermal energy is a form of solar energy as the sun heats the surface of the earth.
- For the PHMH, inefficient crawl spaces and attics are replaced with full basements and/or insulated lofts/2nd stories, providing value added living space.

Zero Net Energy Design

- Zero Net Energy homes bridge the gap between passive house technology using innovative technologies such as:
  - Integration of Hybrid Solar PV/T, water to water GSHP, Desuperheater, 97% efficient ERV with ground to air heat exchanger and cool air flush, radiant floor heating and cooling, 2^{nd} stage hydronic fan-coils for controlling humidity in addition to provision of heating and cooling, state-of-the-art thermal battery system, and 12-24 hr. DC battery system
  - Hybrid AC-DC MicroGrid with Smart Plug technology, Energy Management System (EMS), programmable automated controls (PAC), energy efficient DC appliances, and ultra energy efficient DC powered LED lighting

Value Added Construction Technology

- Innovative design and state-of-the-art construction management can substantially reduce material and labor costs for experienced ICF crews that simultaneously install power lines, Ethernet, plumbing and HVAC/ERV ducting systems, and decorative concrete floors.
- There is potential to reduce labor costs by as much as 50% in comparison with stick-frame and conventional ICF technologies.
- Relatively large ICF hybrid blocks/panels combined with innovative footings technology and bracing systems can allow for achieving 150-200 sqft per man hour.
- Helix micro-rebar can replace the majority of conventional rebar for use with high performance fly ash/pozzolanic concrete with increased durability.

Heat Capacity & Thermal Conductivity

- Since pozzolans (fly ash, slag, etc.) have higher heat capacities and decreased thermal conductivity, they offer the following advantages over ordinary Portland cement concrete:
  - Increased resistance to heat/fire
  - Increased ability to store thermal energy
  - Slower release of that thermal energy for heating structures which enhances energy efficiency
- This makes pozzolanic and Portland cement concrete blends strategically appealing for use with concrete structures, particularly in conjunction with hydronic-radiant heating and cooling systems, allowing for conservation of up to 40% of the energy required for heating and cooling a concrete structure.

Enhancing Affordability via Sweat Equity Programs

- Under supervision, homeowners can:
  - participate in installation of radiant floor tubing for heating and cooling
  - perform interior painting
  - install exterior cultured stone
  - install sprinklers and perform landscaping
- These sweat equity opportunities can substantially reduce construction costs, allowing for homeowners to offset costs of purchasing ultra energy efficient smart homes with home automation technologies for high quality structures.

Model Home Objective

- Provide an energy efficient model home for experiencing the economic advantages of reducing energy loads and increasing quality.
- Utilize superior architecture, engineering, smart home, energy management, and home automation technologies, advanced building materials, and state-of-the-art construction techniques.
- Function as a product distributor and training program for contractors and subcontractors to incorporate state-of-the-art products and services provided by industry partners for construction of energy efficient homes and commercial buildings.
- Use state-of-the-art integrated solar thermal, geothermal heat pump systems, and solar photovoltaics (PV) in order to cost effectively achieve zero net energy homes.

Model Home Marketing

- Once the model home is completed an informative website will be developed and an Internet marketing campaign will be launched for new home construction targeting homeowners, businesses, architects, engineers, and contractors.
- The initial Passive House Model Home (PHMH) will be located in Boise, ID and will be open 10 hr./day six days a week. It will serve as the home office of the home designer, systems architect, contractor training group, and primary distributor of materials & equipment (RM Enterprises, LLC).
- The PHMH will not be sold unless a new model home is built in order to showcase newer more efficient technologies developed by industry partners.

Model Home Concept

- Passive houses are popular in communities where demand for energy efficiency is understood and appreciated through the use of Model Homes (http://www.zehnderamerica.com/how-the-system-works/video_list.aspx).
- Seeing is believing and energy efficient homes cannot be produced fast enough for informed homeowners who tour model homes that display passive house technology, particularly for the purpose of achieving zero-net energy homes.
- One of the keys to mainstream acceptance is integration of passive house technology with conventional architecture and showcasing superior energy efficiency, quality, and affordability.

Superior Building Science & Materials

- More concrete is produced than any other material on Earth. In the foreseeable future, there is no other material that can replace concrete to meet our societies' needs for housing, shelter, schools, and infrastructure. Concrete is an essential part of LIFE.
- In comparison with other building materials, concrete provides superior Structural Strength, Durability & Thermal Mass.
- MIT's Concrete Sustainability Hub and ICF manufacturers are providing state-of-the-art R&D and innovative products which can be used to enhance energy efficiency, quality, and affordability of residential and commercial construction.

Concrete Science & Engineering

- Emerging breakthroughs in concrete science and engineering hold the promise that concrete can be part of the solution for contributing to a sustainable development that encompasses economic growth and social progress while minimizing the ecological footprint.
- This requires a holistic approach in which progress in concrete science translates into innovative structural concrete engineering applications, ranging from concrete pavement solutions for driveways, integral waterproofing including water and waste water treatment, below grade foundations, tunnels, and residential and commercial wall systems that are resistant to hurricanes, typhoons, earthquakes, fires, etc., whose impact on sustainable development are evaluated with advanced environmental-econometric impact studies.

MIT Concrete Sustainability Hub

- The MIT Concrete Sustainability Hub (CSHub), is a dedicated team of interdisciplinary researchers from several MIT departments working on concrete and infrastructure science, engineering, and economics since 2009.
- The MIT CSHub brings together leaders from academia, industry, and government to develop breakthroughs using a holistic approach that will achieve durable and sustainable homes, buildings, and infrastructure in ever more demanding environments.
- The CSHub is focused on Building for **LIFE**: **L**ife cycle thinking * **I**nnovation * **F**iscal responsibility * **E**nvironmental leadership.

MIT CSHub Research Focus

- ***Materials Science:*** The CSHub uses a range of modeling techniques, starting at the atomic level, to predict structures and properties that will improve how cement is designed, reduce CO_2 emissions, and enable US leadership in future cement technologies.
- ***Buildings & Pavements:*** The CSHub explores innovative solutions for concrete engineering applications in buildings and pavements. For buildings, research focuses on durability, energy efficiency, and resiliency.
- ***Economics & Environment:*** The CSHub adopts a long-term approach to decision-making, considering the entire lifetime of a building. Through improved life cycle assessment and life cycle cost analysis techniques, the CSHub can help stakeholders wisely use limited funding for infrastructure projects while considering environmental impacts.

Innovative Concrete Technologies

- Energetically Modified Cement (EMC) and Alternative Cementitious Materials (ACM) have been developed using up to 95% class C fly ash and other industrial waste products and pozzolans for displacement of more expensive portland cement.
- Fiber Reinforced Concrete (FRC) using polymers to reduce cracking and provide tensile ductility similar to steel, thereby reducing or eliminating the need for reinforced steel and associated labor.
- Engineered Cementitious Composites (ECC) using custom concrete mix designs for incorporation of EMC & FRC for specific applications with self-healing capabilities.

Material Science

- Increasing energy efficiency, durability, and life cycle analysis of structures begins with choice of building materials.
- A systems architecture and engineering approach that utilizes state-of-the-art HVAC technologies such as solar thermal, solar PV and water to water GSHP technology with COPs of up to 7.0 can provide unprecedented production efficiencies in conjunction with innovative insulated concrete form (ICF) technologies.
- Concrete and water have very appealing thermal mass properties, e.g., heat capacity and thermal conductance (collectively referred to as thermal capacitance) which are vastly superior to wood. When the two materials are strategically utilized in buildings, unprecedented energy efficiencies can be achieved.
- While material costs can be up to 12% higher for ICF structures, preliminary research reveals that a systems approach can potentially reduce labor costs by well over 50% in comparison with conventional ICF block and stick-frame construction technologies.

Systems Architecture & Engineering

- Strategic design minimizes cutting of ICF blocks for windows and doors, etc.
- FastFooting and monolithic concrete pouring technology eliminates removal of forms.
- Hybrid big block technologies such as that developed by Nudura (which requires no assembly on site can be at least three-fold more productive than smaller ICF blocks and wood-frame construction) when used in a system approach.
- Innovative quick bracing technology provided by the manufacturers of FastFooting (Fab-Form).
- Structural lightweight concrete (the economical use of foam aggregates to increase air entrainment is very appealing for use with strategic mix designs and results in decreasing the volume of concrete for footings and minimizes steel reinforcement).
- Self-consolidating concrete including the use of super plasticizers which can reduce labor by 80% during pouring. This approach minimizes the need for vibration and results in a 50% savings in labor required for pouring concrete.
- Steel fiber admixes substantially enhances self-consolidation and minimizes the need for conventional rebar, particularly for monolithic pour systems such as FastFooting.
- State-of-the-art construction management.
- Experienced ICF crews.

Thermal Mass of Concrete Structures

- Even temperature: Concrete is a material of high thermal mass. That means it changes temperature only slowly. ICF walls, in fact, have about 3-5 times the thermal mass of a conventional wood frame wall. The result is that the temperature of the building tends to be very stable instead of overheating and getting cold when the furnace (or AC cycles on and off every half hour.
- Fewer drafts: An ICF wall consists of two layers of a fairly air-tight material (foam or cementitious composite) sealed in the center with concrete. This contrasts with wood frame, which is assembled of many rigid pieces to leave thousands of tiny air gaps. Recent studies of new wood homes show air changes per hour of an average of 0.5. But ICF houses have consistently been measured at much lower change rates (down to .11), for many fewer drafts.

Radiant Heating & Cooling - Continuous Concrete Structures - Temperature Differential

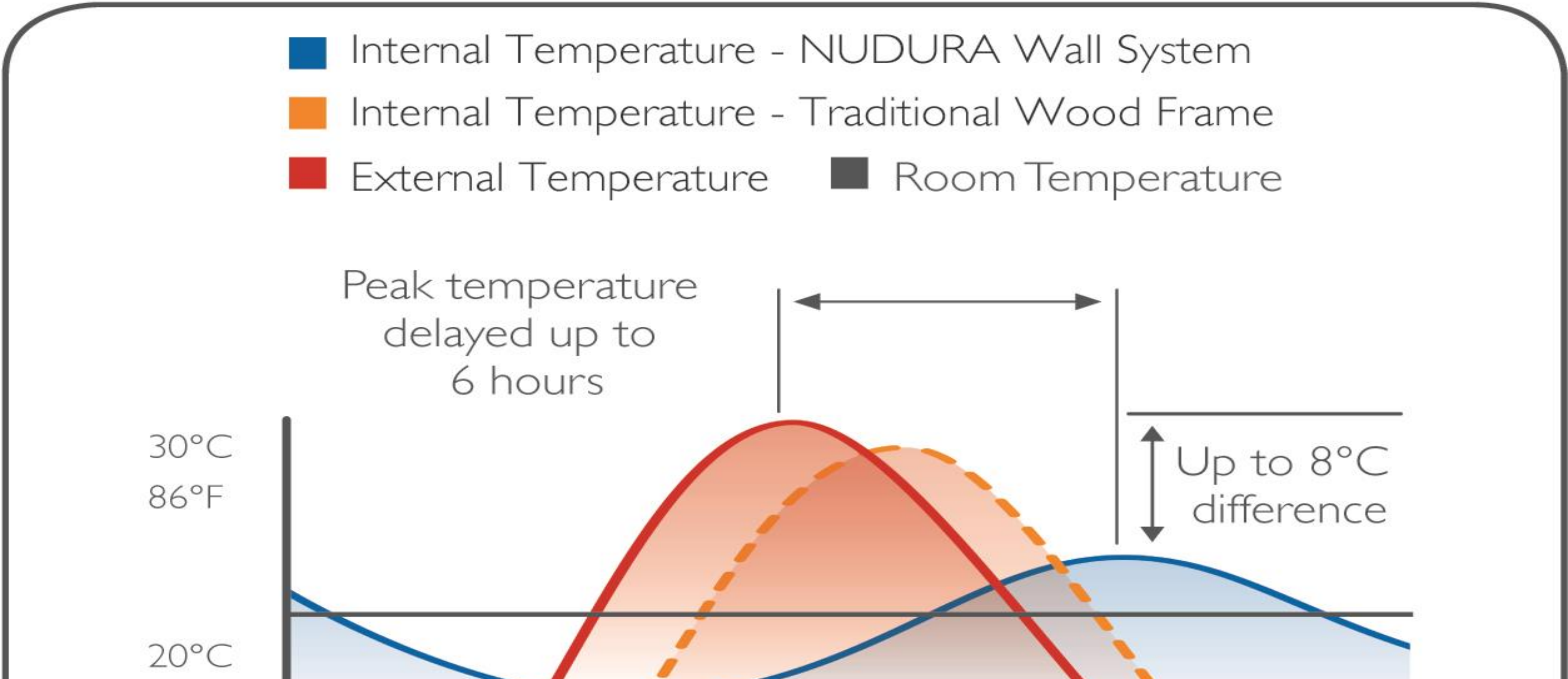
- Fewer hot and cold spots: Most ICF structures have two layers of insulation that are completely uninterrupted. The uninsulated portions of wood frame walls usually add up to about 25% of total area. The result is that ICF structures have virtually none of the cold spots or hot spots one feels when walking along frame walls in winter or summer.
- Consistent floor-to-ceiling temperature via integration of ICF structures and radiant heating & cooling: Since ICFs have consistent thermal mass and insulation at the floor level and up and down the walls and in vaulted ceilings, measurements have shown an air temperature differential in super-insulated air-tight ICF houses from floor level to ceiling level of only a few degrees. The difference can be 4-5 times this in conventional stick-frame houses.

Capitalizing on Concrete’s Thermal Mass

- Concrete walls conserve heat or cooling, acting as an energy sink. According to the Portland Cement Association this contributes/comprises about 6% of the needed energy for a structure.
- Based on thermal mass, when floors, interior walls, and vaulted ceiling structures are also constructed of ICF materials, solar thermal, passive solar radiation, and the concrete structure can combine to conserve/contribute over 24% of the needed energy of the structure.
- Concrete floors, concrete countertops, strategic eaves, solar thermal radiant floors, strategic orientation and passive solar window/glazing design could potentially conserve/provide over 40% of the volume of energy required for the PHMH.
- When ICF structures are integrated with solar PV/T technology and solar thermal batteries comprised of strategically designed super-insulated concrete cisterns, this could potentially provide 100% of the volume of energy required for the PHMH, e.g. achieving zero net energy (ZNE).

ICF Exterior Wall System

Stabilizing effect of thermal mass on internal temperature.



Hybrid Thermal Storage System

- As portrayed above, passive thermal storage is incorporated into buildings to smooth out temperature swings, delay heat entry (such as concrete and solar thermal collectors that absorb solar heat and conduct it into a structure over the course of several hours), absorb energy surpluses such as solar heat or heat from computers or other appliances, or to store heat as part of a passive solar heating system.
- Though the above illustration is based on a specific product for a particular ICF manufacturer, similar though varied results would be obtained from different products with lower or higher thermal mass (volume of concrete used in walls, floors/ceiling and roof structures, etc., as a component of a thermal battery storage system).
- For an all ICF/concrete structure the volume of thermal mass and ability to stabilize thermal temperature within that structure would be dramatically enhanced via an integrated solar thermal HVAC system.

High Thermal Mass & Energy Storage can Result in 50% Reduction in Solar Collectors

- High thermal mass construction such as ICF/concrete structures (external and internal walls, floors and vaulted ceiling), radiant heating and cooling systems that minimize ΔT, a super-insulated seasonal energy storage tank, ground to air heat exchanger integrated with 97% efficient ERV/HRV including oversized fan coils and cool air flush, a hybrid electric thermal storage system using a water to water GSHP with a COP over 7.0, and programmable automated controls can conserve up to 50% of the energy required to heat the structure.
- This could reduce the size of the solar thermal collector system by 50% without affecting the performance of the space heating or DHW systems.

Common Distribution Systems

Distribution System	Temperature
Forced air	Air, 120 – 150 °F
Hydronic baseboard	Water, 150 – 180 °F
Hydronic radiator	Water, 120 – 180 °F
Hydronic radiant floor	Water, 85 – 100 °F
Domestic hot water systems	Water, 120 – 140 °F

One of the most energy efficient storage and distribution systems is achieved using solar thermal water and hydronic radiant floor heating and cooling in conjunction with a concrete structure.

High Heat Capacity & Moderate Conductivity

- ICF exterior walls and connected floors have a high storage capacity with moderate thermal conductivity. Thus, it provides the most useful level of thermal mass sandwiched between EPS foam layers. This helps to stabilize the internal temperature from day to night temperature fluctuations.
- Increasing thermal mass by constructing interior walls, floors, ceilings/roofs with ICF and concrete slabs could substantially increase energy conservation.
- This is particularly true if a thermal battery, such as a super-insulated concrete cistern can be economically utilized to store solar thermal energy. Such an integrated system which may include a water to water GSHP and Desuperheater is used to bridge passive and active thermal storage technologies for development of an innovative hybrid thermal energy storage system.

Drain Back Solar Thermal Collector Systems

- Drain back systems provide an 18% increase in energy efficiency compared to closed systems using glycol.
- Life cycle is increased by 33% vs. a glycol system.
- System is substantially simplified vs. a closed pressurized system:
  - No expansion tank required
  - No pressurized tank required
  - No check valve required
  - No air valve required
  - No pressure release valve required
  - No heat exchanger required
  - No heat dump equipment required
- Labor and materials for installation of a drain back system are less expensive.
- Stainless steel or brass circulators must be utilized in the solar loop since air can cause oxidation and lead to rusting of cast iron circulators for open systems.

Hybrid Electrical Thermal Storage (ETS)

- In addition to producing solar thermal energy, excess DC power produced by hybrid solar PV/T collectors can be converted into solar thermal energy during cool seasons.
- In conjunction with an integrated water to water GSHP and Desuperheater, the ETS sub-system can provide hot water for radiant floor and fan-coil heating systems. It can also generate DHW.
- This provides an economical alternative to selling energy back to the grid, particularly where that energy cannot be sold and will not be reutilized. In regards to energy storage, for hybrid AC-DC Microgrids this option is substantially more energy efficient than net-metering systems.

ETS via Solar, Wind & GSHP Resources

- ETS systems can be charged with off-peak power, solar, or wind electricity, or they can be used to store heat from a heat pump.
- The length of storage time depends on the size of the system, but generally is on the order of 6-24 hours.
- Off-peak grid power hours occur daily, so the systems are typically sized to take advantage of this charging time each day.
- Renewable systems may be sized for longer times to provide thermal energy and DHW during periods of cloudy days.

Hybrid Solar & W2W GSHP Systems

- Another use for solar thermal systems is in combination with a ground loop and ground source heat pump. The solar panels can be used to provide heat to a distribution system for space heating, or to a thermal storage tank.
- During times when the solar thermal heat is not needed for domestic applications, heated fluid from the solar panels can be circulated through ground loop. The solar thermal heat can help replenish the heat taken from the ground by the ground source heat pump.
- The ground can also act as additional “thermal storage” since the heat from the solar panels raises the temperature of the soil.

Heating Dominated Climates

- For heating-dominated climates, sending heat from solar panels to the ground over the course of the year helps to balance the amount of heat taken from the ground in the winter by the heat pump. One such system, described in Wang, Qi, Wang, & Zhao (2009), uses solar thermal panels, a 211-gallon indoor tank, a ground loop in the soil outside the building, and a heat pump.
- The solar panels are meant to improve the energy efficiency of the system and prevent the ground temperature from decreasing over time. There is a similar system located in Fairbanks, Alaska at Weller Elementary School. Solar panels and a ground source heat pump at the school provide heat to a water tank in the building. During the summer season, heat from the solar panels is used to replenish heat in the soil around the ground loop.

Optimizing Energy Efficiency

- Thermal storage has the potential to increase the efficiency of certain types of heating systems, such as ground source heat pumps, by reducing cycling. Ground source heat pumps with buffer tanks can also increase efficiency and reduce machine wear-and-tear by allowing longer and fewer run times. System efficiency depends on the specific system design and amount of standby loss.
- Thermal storage can also potentially lower operating costs by enabling the use of excess solar electricity or lower cost off-peak electricity when offered by the utility. This can reduce costs for heating systems with a significant electrical power draw (such as heat pumps) if the operating cost of the storage system itself does not negate the savings.

Foam Aggregates for Cellular Concrete

- Fluorochemical foam stabilizers are used in combination with surfactants to yield foams that are exceptionally stable in cementitious media.
- The stabilized foams that incorporate these fluorochemical agents are useful as novel ultra-lightweight foam aggregates in concrete compositions of tailorable density, strength, and other properties.
- Flowability is substantially increased as is the ability of the concrete to self-consolidate. By adding a steel fiber admix, use conventional rebar can be minimized, particularly for monolithic pouring systems that can reduce labor by over 50% while providing structurally lightweight concrete.
- The hydrostatic pressure of foam aggregates reduces blow-outs, allowing for pouring walls as high as 30’ without difficulty.

Stable Ultra-lightweight Aggregates

- The high stability and resilience of the resultant foams enable their use as novel stable ultra-lightweight aggregates in combinations with other concrete components including but not limited to water, cement, hydraulic hydrated lime, ground granulated iron blast furnace slags, sand, silica, stone, other, natural and byproduct pozzolanic materials, as well as chemical admixtures such as water-reducers and superplasticizers.

Advantages of Foam Aggregates in Freshly Mixed Concrete

- When compared to conventional normal-weight concrete, the freshly mixed (plastic) concrete compositions incorporating these novel foam aggregates in wet cementitious compositions can demonstrate several advantages such as improved plasticity, ductility, workability, flowability, resistance to freeze-thaw, and ease of transport; reduced water demand, bleeding, and segregation; and easily tailored properties such as density, viscosity, and thixotropy.

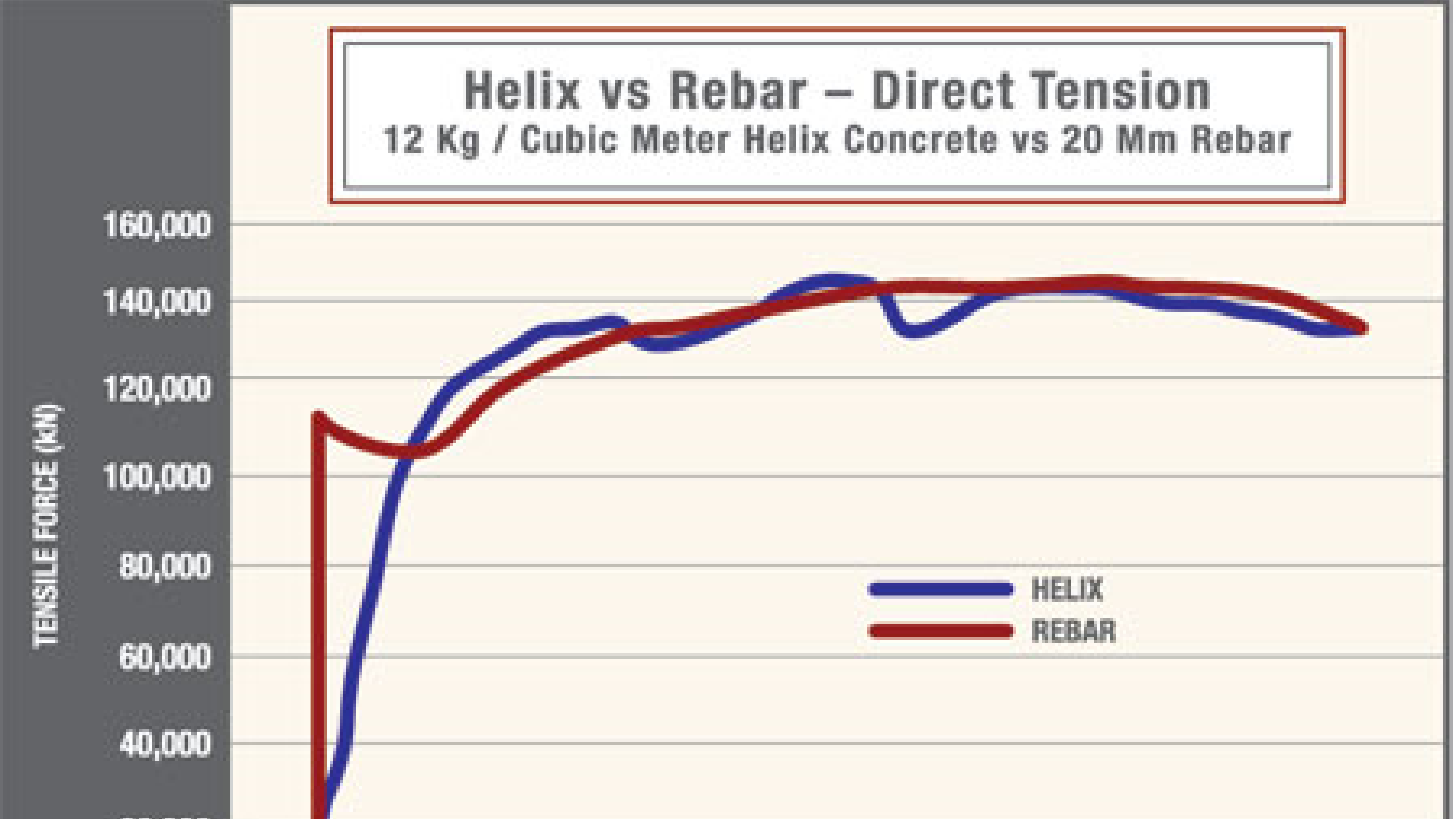
Advantages of Foam Aggregates in Cured/Hardened Concrete

- When compared to conventional normal-weight concrete, the hardened concretes derived from compositions incorporating these novel foam aggregates can demonstrate significant improvements in workability, ease of machining, water-tightness, and deicer scaling; increased resistance to sulfate, alkali-silica reactivity, and freeze-thaw; and easily tailored properties such as density, compressive strength relative to density, thermal resistance, and acoustic characteristics.

Two levels of components have now been installed. The Zont bracing is attached to align the wall and fix into exact location with stakes at the base of each vertical strongback.

Helix Twisted Steel MicroRebar

- Nearly all steel fibers are limited to replacing temperature crack control steel reinforcement (rebar/mesh) in concrete. At present, Helix MicroRebar is the single exception, and can be used as replacement for structural reinforcement under the provision of ACI 318 section 1.4. This section allows new materials of construction, such as Helix, to be to be used in lieu of code-specified reinforcement after undergoing a period of development and testing before being specifically covered in a code. Both the IBC and IRC codes reference this ACI 318 section to allow the use of Helix Micro Rebar.
- To satisfy the ACI 318 requirements, Polytorx LLC, which manufactures Helix, contracted with an internationally certified IAS/ICC laboratory to perform a series of tensile strength tests.


Helix vs Rebar – Direct Tension
12 Kg / Cubic Meter Helix Concrete vs 20 Mm Rebar
160,000
140,000
120,000
100,000
80,000
60,000
40,000
TENSILE FORCE (kN)
HELIX
REBAR

Helix MicroRebar ASTM Test Results

- The above referenced test results were then carefully analyzed and compared with the results of various ASTM tests and more than 10 years of field performance data, to create the design model now used to calculate how much Helix is needed to replace rebar and mesh in both structural and non-structural applications.
- At this time, the use of Helix is covered for Class A and Class B structures under ESR 3441 and ER 0279. Class C structures that use Helix micro rebar are covered under Helix Design Method Evaluation Report dated March 7, 2013 and require a professional engineer stamp for the specific structural design, which can be obtained in all 50 states and Canadian provinces.

ISO Certified Design Manual

- Helix Steel recently earned IAPMO's Uniform Evaluation Service (UES) Evaluation Report ER-279 on Helix 5-25 Micro-Rebar (http://www.core-construction-products.com/pdfs/ACI-318-IBC-IRC-Evaluation-report-Helix-Steel-Micro-Rebar-Alternative-to-Steel-Rebar-Concrete-reinforcement-Vertical-Applications.pdf)
- Helix Micro-Rebar 5-25 is the only discontinuous concrete reinforcement product in the world that now has a ISO certified design manual that can be followed to design vertical applications (such as walls) with Helix as the primary concrete reinforcement.

Advantages of Helix Micro Rebar

- Helix Eliminates Placing Errors. Helix avoids placement errors since it is distributed throughout the concrete matrix. Traditional reinforcement's effective strength is decreased by up to 50% when misplaced. Placing chairs, and their potential for weakening the concrete, are also eliminated.
- Helix Provides a 40% Plus Stronger Concrete Section. Helix is a multidirectional reinforcement that increases shear strength and decreases the need for stirrups.
- Helix Allows the Concrete to Absorb 200% Plus More Energy. Helix adds durability and impact resistance to the concrete which is excellent for heavy loads and seismic events.

Advantages of Helix Micro Rebar cont.

- Helix has Excellent Crack Control Properties. Helix is designed to keep cracks tight and short when they develop allowing the concrete to micro crack but not develop a large, dominate crack.
- Helix is a Safer, Discontinuous Reinforcement System. Helix does not allow for a complete failure of the system due to corrosion; unlike traditional reinforcement which is continuous and electrically connected.
- Helix Helps Increase Worksite Safety. Helix reduces injuries due to cuts (placing), strains (lifting) and tripping/falling (maneuvering through the grid) traditionally associated with rebar/mesh.

Advantages of Helix Micro Rebar cont.

- Helix is electroplated with zinc and has been tested in de-icing agents to resist rusting 3 times longer than standard rebar/mesh without coating.
- Helix reduces construction time by eliminating laying, tying, and inspections and in most cases can eliminate the need for pumping and void development in highly congested steel locations.
- Helix reduces steel reinforcing costs by at least 20% through reducing labor associated with rebar/mesh placement along with reduction of scrap, chairs and overlap splicing steel.
- Helix is made from 50% recycled steel and less overall weight of steel is used for reinforcing concrete.

Steel Fiber can Reduce Labor by up to 50%

- Twisted steel micro-rebar (TSMR) or possibly other steel fibers and monolithic pouring systems allow for reducing or eliminating rebar and mesh steel reinforcement.
- TSMR fibers are one inch long strands of 245 KSI carbon steel electroplated with zinc for corrosion resistance.
- The twisted shape resists tension similar to the tension required to pull out nails vs. screws.
- The TSMR fibers can be effectively used as an admix in engineered cementitious composites that are lightweight with increased compressive strength and durability.

Seismic Zone IBC-C/UBC-2B for Boise, ID

Dosage of Helix 5-25 Based on Footing and Rebar Configuration (lb/yd^3)

Rebar Configuration	Steel reinforcement ratio (in^2/ft)	Footing thickness				
		8 inches	10 inches	12 inches	14 inches	16 inches
#4 at 6"	0.40	Note 4	33.5	30.1	27.4	25.0
#4 at 8"	0.30	27.4	25.1	22.9	19.0	17.3
#4 at 10"	0.24	22.2	20.4	16.8	15.1	13.7
#4 at 12"	0.20	18.7	15.4	13.9	12.6	11.5
#5 at 8"	0.47	Note 4	Note 4	34.9	Note 4	29.0
#5 at 10"	0.37	33.1	Note 4	27.9	25.4	21.5
#5 at 12"	0.31	27.9	25.8	23.5	19.6	17.8

Notes:

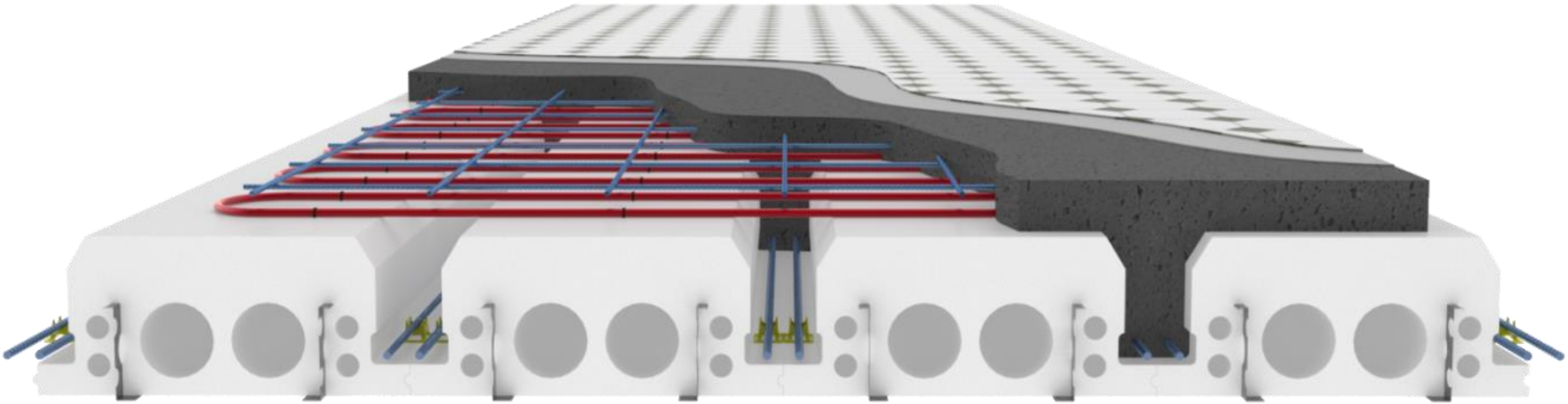
1. Table is based on concrete with a minimum specified compressive strength of 3,000 psi.

2. Table values are calculated using a concrete cover for the rebar of 3 inches from the bottom of the footing
3. If rebar is placed at the center of the thickness, Helix dosage may be multiplied by a factor of 0.75

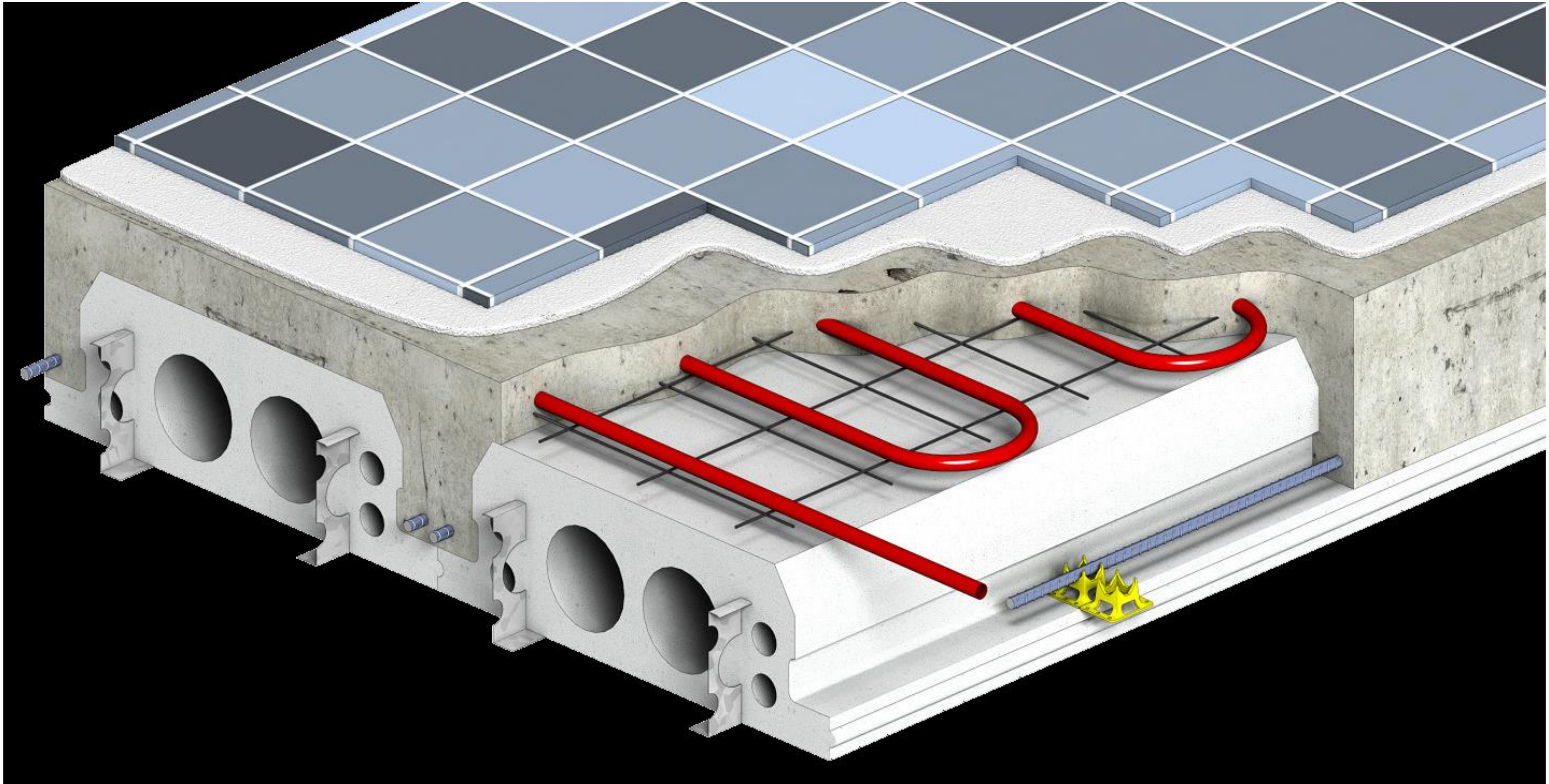
Optimal Balance of Helix MR & Concrete

- At \$2.15/lb plus shipping, Helix MR is substantially more expensive than regular weight concrete which costs \$0.025/lb at 4,000 lb/yd^3 or \$100/yd. By strategically designing concrete structures, overall costs for steel reinforcement and labor for installation can be minimized.
- For example, by increasing the footing thickness from 8” to 16”, the steel reinforcement ratio drops by 50% from 0.40 in^2/ft. to 0.20 in^2/ft. For #4 rebar specification at 12” spacing, this reduces the Helix MR dosage from 18.7 lb/yd^3 to 11.5 lb/yd^3, representing a 39% decrease in costs for Helix, but doubles the cost of concrete for footings.
- Due to the relatively small steel reinforcement ratio required for Helix MR, calculations reveal that total footing costs are reduced by 38% using the equivalent of #4 rebar at 12” spacing (18.7 lb/yd^3 Helix MR dosage) for 8” thick footings in seismic zone C.

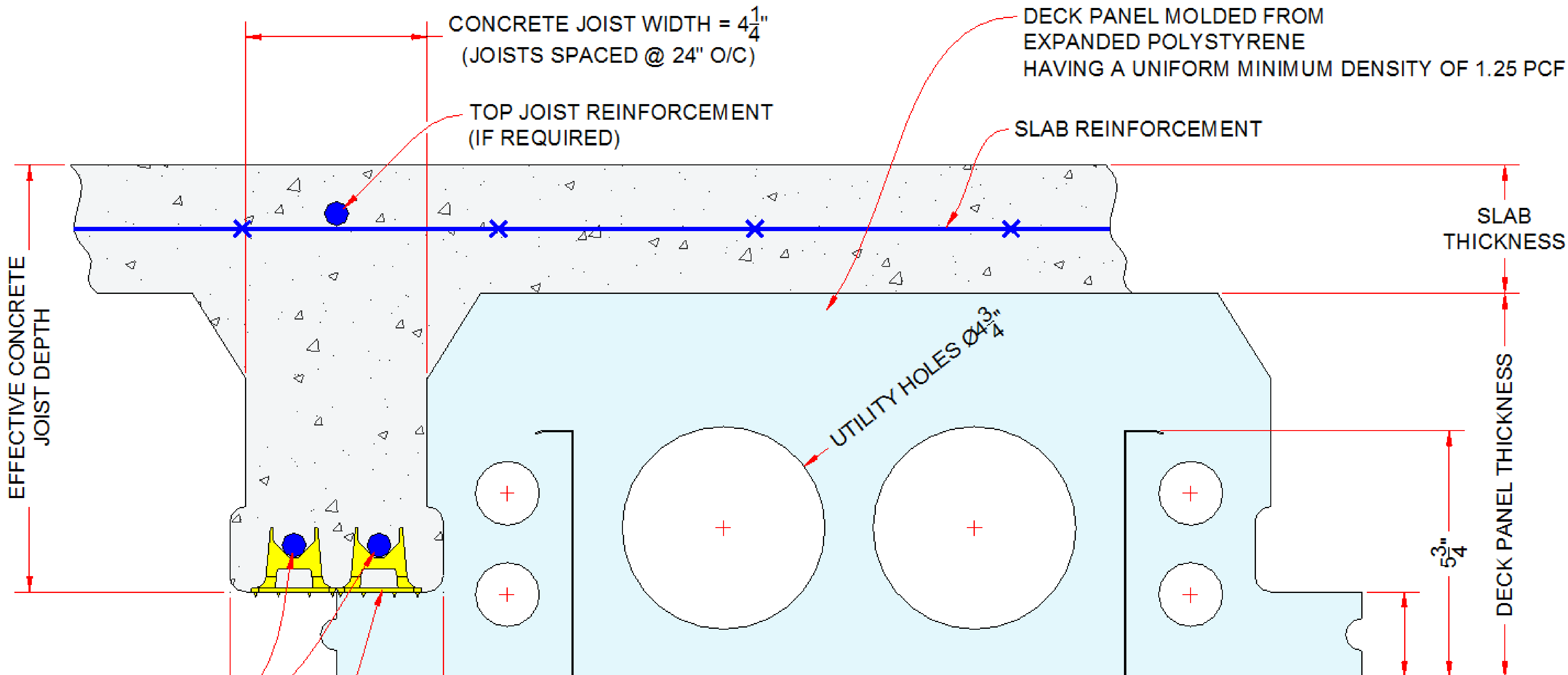
Insulated Quad-Deck T-beam
Suspended Floor & Vaulted Ceiling Systems



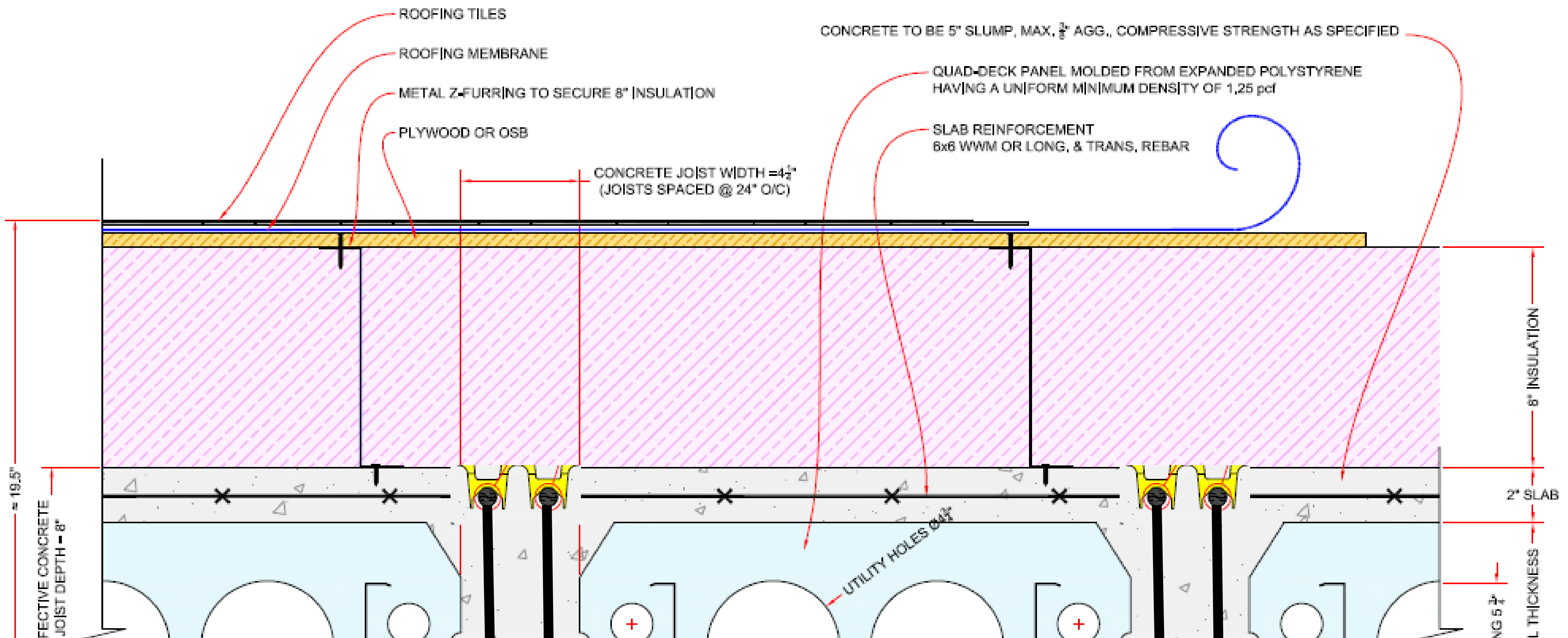
Quad-Deck Radiant Flooring



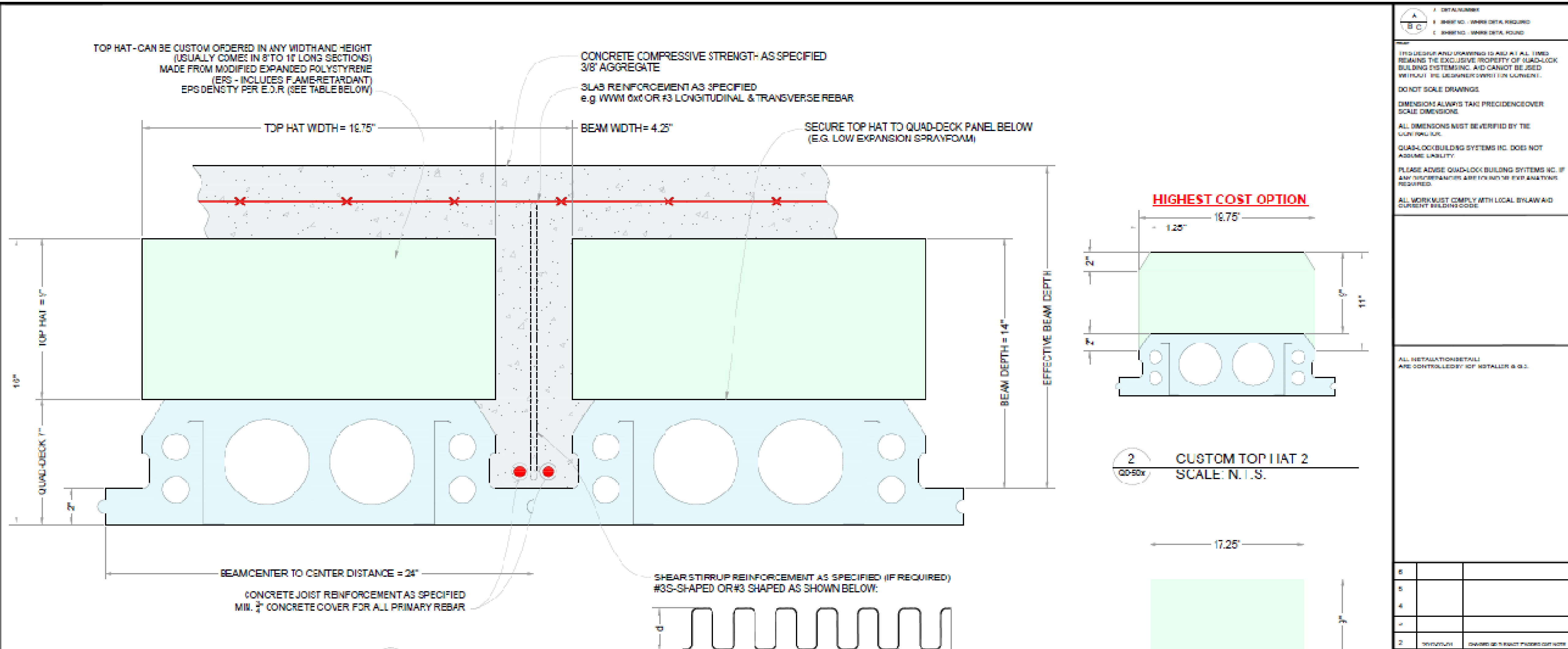
Quad-Deck Panel Dimensions



Quad-Deck Nominal R-74
Vaulted Ceiling Assembly ~R-148

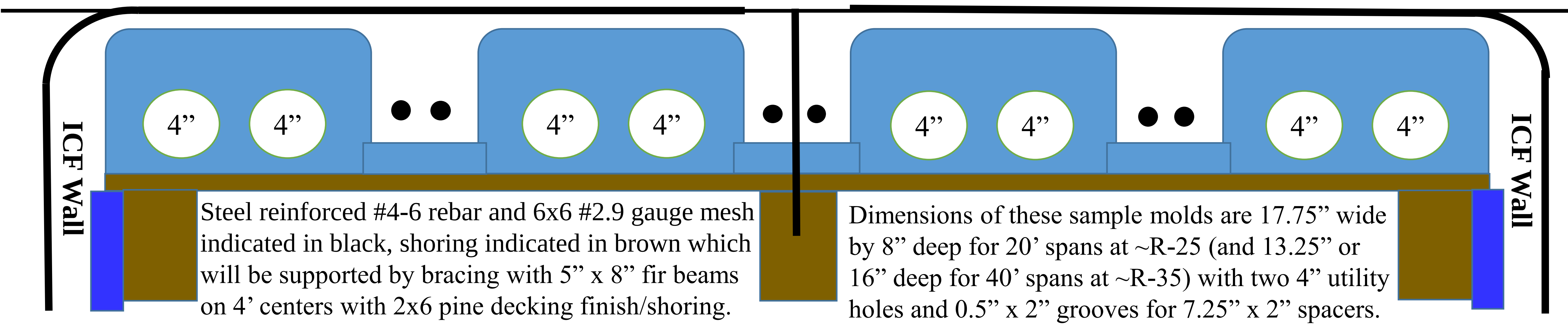


Quad-Deck Top Hat Design for 40’ Spans



Custom T-Beam EPS Assembly & Shoring

- Similar to the top hat concept, a custom EPS mold could be developed for vaulted ceilings that are properly shored with a finished ceiling material such as tongue and groove pine with fir beams on 4’ centers.
- The depth and width of the vertical portion of the T-Beam is determined by the size of the EPS blocks inserted between existing ICF walls which will vary depending on length of span and loads.



Chilled Concrete T-Beams

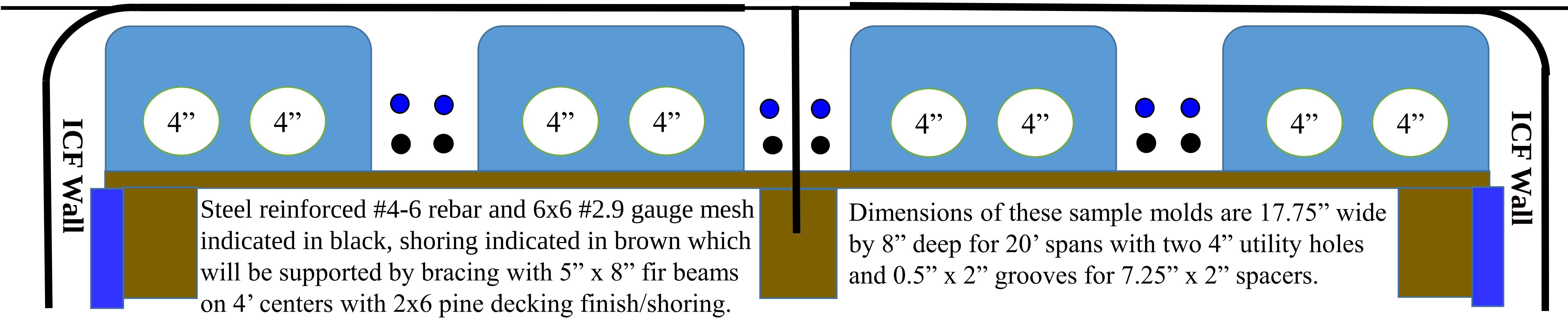
- A chilled beam is a type of convection HVAC system designed to heat or cool large buildings. In this case, pipes of water are passed through a concrete T-Beam (a heat exchanger) integrated into the suspended ceiling system.
- As the beam chills the air around it, the air becomes denser and falls to the floor. It is replaced by warmer air moving up from below, causing a constant flow of convection and cooling the room. Heating works in much the same fashion, similar to a steam radiator.

Types of Chilled Beams

- There are two types of chilled beams. Some passive types rely solely on convection whilst there is a radiant/convective passive type (which could include concrete T-Beams) which cools through a combination of radiant exchange (40%) and convection (60%) which can provide higher thermal comfort levels, while the active type (also called an "induction diffuser") uses ducts to push ("induce") air toward the unit (increasing its heating and cooling capacity).
- The chilled beam is distinguishable from the chilled ceiling. The chilled ceiling uses water flowing through pipes like a chilled beam does; however, the pipes in a chilled ceiling lie behind metal ceiling plates, and the heated and cooled plates are the cause of convection and not the pipe unit itself. Chilled beams are about 85% more effective at convection than chilled ceilings.

Chilled Concrete T-Beam Floor

- PEX tubing is placed in the floors and vaulted ceiling assemblies for use as chilled concrete beams.
- For vaulted ceiling applications, the 2”x7.25” spacers can be replaced with a waterproof membrane prior to pouring concrete, thereby increasing the efficiency of the chilled concrete beam placed flush with the pine tongue and groove finished ceiling.

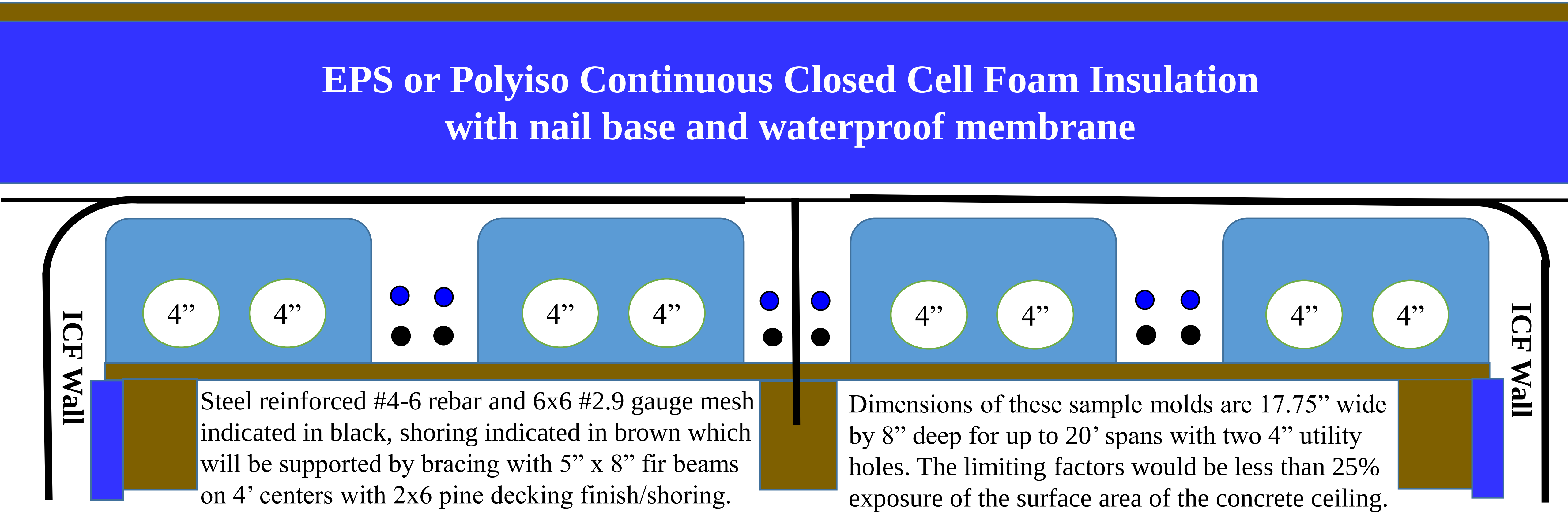


Chilled Concrete T-Beam Design

- As illustrated below, the structural concrete T-Beams would serve as chilled T-beams.
- This would require increasing the volume of foam insulation placed over the concrete T-Beam assembly.
- In addition, in conjunction with a decorative pine tongue and groove ceiling, the 2”x7.25” foam spacer would be removed, thus increasing the effect of the chilled concrete beams.

Chilled Concrete T-Beam - Vaulted Ceiling

- PEX tubing is placed in the floors and vaulted ceiling assemblies. The vaulted ceiling assembly would eliminate the 2”x7.25” EPS spacers in order to enhance efficiency of cooling.



Chilled Concrete T-Beam Efficiency

- Though the concept that cool air sinks is appealing for creating chilled concrete T-Beams, only about 25% of the ceiling area is exposed, and concrete is less conductive than metal which is usually the material of choice for chilled beams.
- In addition, the ¾” knotty pine ceiling and 5”x8” rough cut timbers would virtually prevent much of the cool air radiance emitted by the concrete T-Beams from cooling the space.
- Hence, techno-economic factors indicate that optimizing cooling using radiant floor technology with decorative concrete floors would be the most cost-effective approach unless economic hydronic fan-coils can be used to increase both the radiant and convective cooling efficiency of concrete chilled beams.

T-Beam EPS Member/Block Pricing

- Price per 8’ EPS member piece (Northwest Foam):
  - 2" x 7.25" x 8’ spacer - $2.90 (not needed with knotty pine ceiling finish)
  - 8” x 17.75” x 8’ block - $28.80
  - 13.25" x 17.75” x 8’ block - $47.88
  - 16” x 17.75” x 8’ block - $54.98

- Price of EPS T-Beam form per ft.^{2} with spacers (well over 50% less than Quad-Deck Panels while providing superior insulation and strength due to design)
  - 8" x 17.75 “ block - $1.98 ft.^{2}
  - 13.25" x 17.75” block - $3.17 ft.^{2}
  - 16" x 17.75” block - $3.78 ft.^{2}

Custom T-Beam Pricing & R-values

- For concrete priced @\$110/yd^3):
  - 8” EPS Form Assembly: R-25 = \$1.96/ft^2 plus \$1.09/ft^2 per 2” slab and \$1.43/sqft per 3” slab (for vaulted ceiling up to 20’ spans)
  - 8” EPS Form Assembly: R-25 = \$1.96/ft^2 plus \$1.09/ft^2 per 4” slab and \$2.18/sqft per 4” slab (for up to 20’ spans including radiant floors)
  - Either 13.25” or 16” EPS Form Assembly: R-35 to R-45 with utility holes = \$3.20/\$3.85ft^2 plus \$2.18/ft^2 per 4” slab (for up to 40’ spans over garage including radiant floors).
  - Insulation values without utility holes would be ~R-4/inch, e.g., ~R-32 for the 8” block, ~R-53 for the 13.25” block, and ~R-64 for the 16” block.

  (Concrete pricing is based on full retail pricing for minimum 3,000 psi tensile strength.)

Custom T-Beam Shoring Requirements

- Shoring Loads - @150 lb/ft^3 for concrete
  - 8" EPS T-Beam with 2" slab = 0.427 ft^3 = 64 lb/ft^2 (for 20' span vaulted ceiling)
  - 8" EPS T-Beam with 4" slab = 0.594 ft^3 = 89 lb/ft^2 (for 20' span radiant floors)
  - 13.25" EPS T-Beam with 4" slab = 0.854 ft^3 = 128 lb/ft^2 (40' span floor/ceiling)
  - 16" EPS T-Beam with 4" slab = 01.03 ft^3 = 155 lb/ft^2 (40' span ceiling/floor)

- Shoring Requirements
  - 5x8 permanent Doug Fir Beams on 4' centers with concrete anchors and 4x4 temporary shoring between 5x8 Doug Fir Beams with either 2x6/2x8 stained and finished Pine Decking, or 1x6/1x8 with additional 0.5 to 0.75" plywood for additional reinforcement if required.

Concrete T-Beam Decking & Shoring Costs

- Decking
  - 1x6 t&g #3 pine $0.73/ft.^{2}
  - 1x8 t&g #3 pine- $0.70/ft.^{2}
- Shoring
  - Rough cut timbers based on 4' centers:
    - 5x8 Doug Fir rough sawn timbers $4.40 per lineal foot up to 24', over 24' the price is $6.40 per lineal foot (a 5x8-20' beam is $88.00, and a 5x8- 30' beam is $192)
    - 5x8 beams = $4.40/ft. = ~$1.05/ft.^{2} based on 4' centers
- Sheetrocking, taping, mudding, sanding & painting ceiling
  - ~$2.00/ft.^{2} (about the same price as finished decking, 0.5" plywood and beams @ $2.325 when reduced labor and costs of shoring is considered)

Fir Beams with Pine Tongue & Groove Ceiling

These beams or similar type material (milled logs, or glulams) would run perpendicular to ICF panels in the loft/2nd story of the PHMH

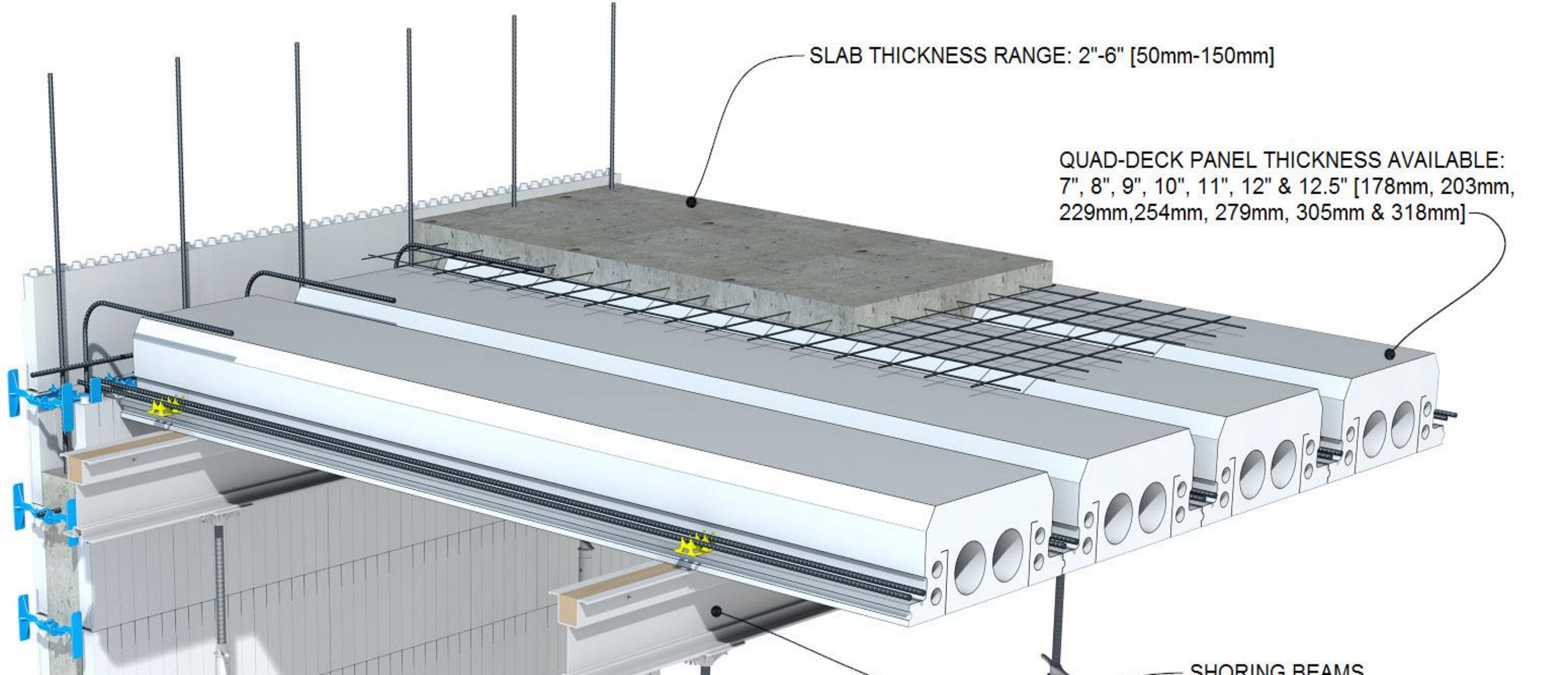
Assembly R-Values vs. Nominal R-Values

- Similar to the assembly value of ICF walls which can virtually double the nominal R-value, the same can be accomplished for vaulted ceilings using ICF technology.
- This effectively reduces the volume of EPS foam insulation required to achieve a targeted R-value.
- For example, to achieve a targeted assembly R-60, a nominal R-value of 35 would probably be sufficient for an ICF assembly.
- Hence, an 8” T-Beam mold with 2.5” slab would provide a nominal R-16 using 2 lb. density. To achieve an assembly value of R-60 would require as little as an additional 5.5” of 1 lb. density EPS foam with a 7/16” OSB nail base.

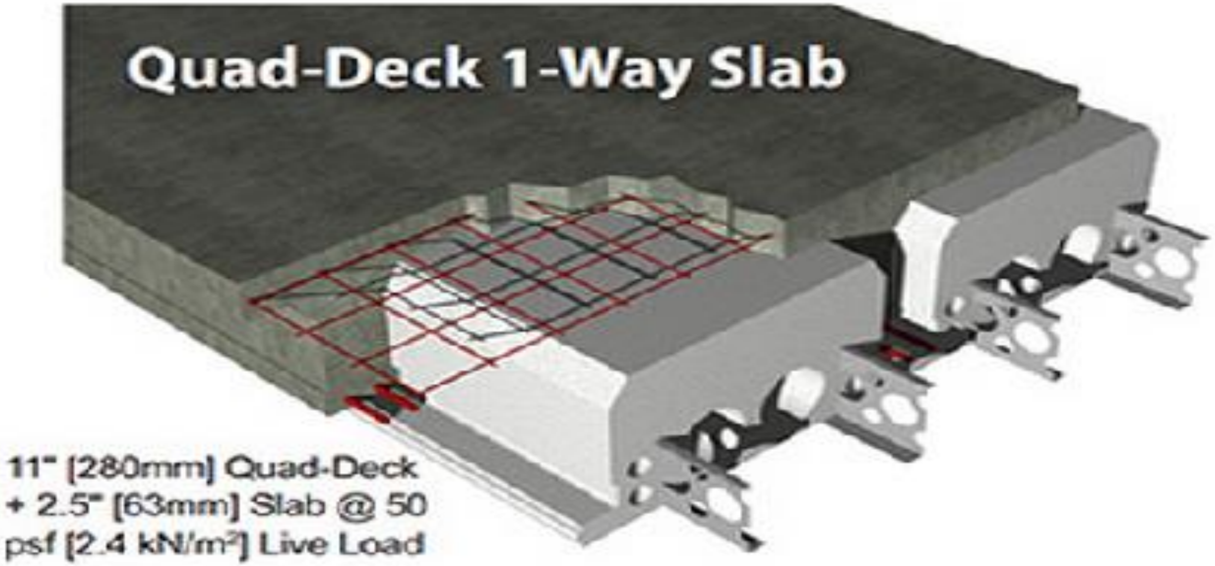
ICF Technology Provides a Tight Envelope

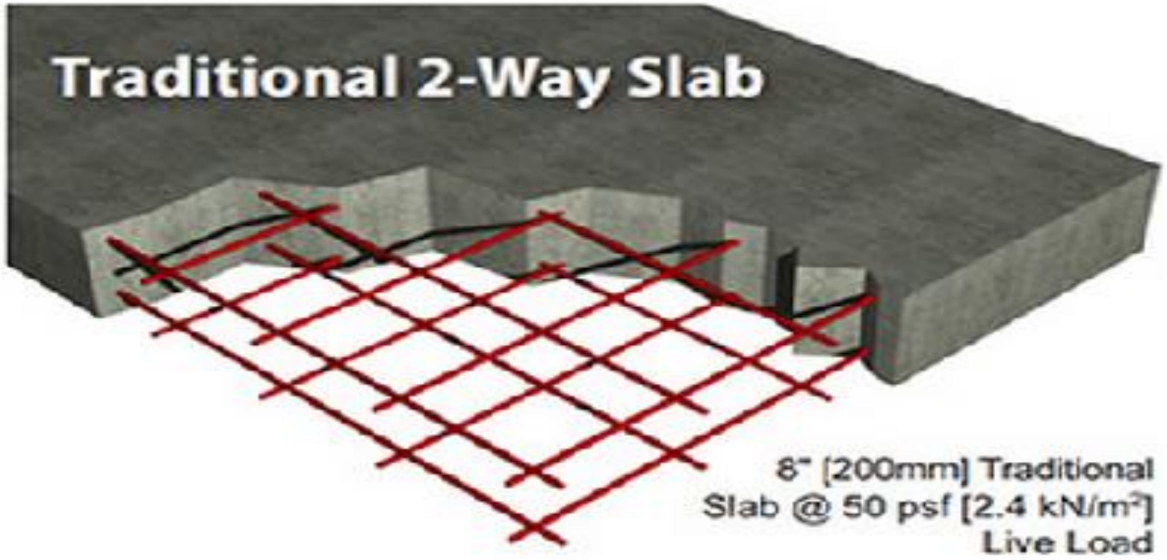
- Unlike wood construction, even with closed cell foam insulation, carefully constructed ICF assemblies can be essentially air tight, e.g., providing 0.1 ACH@50 Pascals.
- Reducing air infiltration is often more important than insulation regarding energy efficiency. If air can circumvent insulation this can render the entire R-value assembly considerably less effective.
- Another advantage of having a concrete envelope is structural integrity and protection against fire and natural disasters including earthquakes, floods, hurricanes, tsunamis, and mudslides, etc.
- The additional costs for constructing the ICF vaulted ceiling amount to about $1.50/ft.^{2} which is offset by eliminating the need for sheetrocking, taping, mudding, sanding and painting and much of the labor associated with conventional shoring.

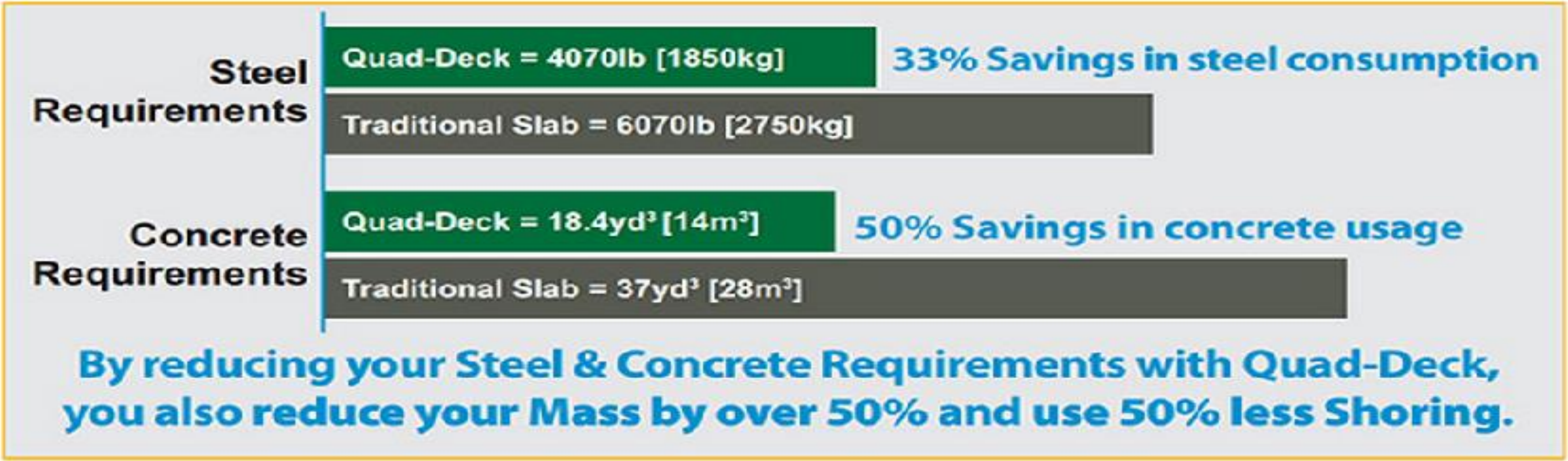
Quad-Deck Ceiling/Floor Application



Single Span = 25' [7.6m], Floor Area = 1500 sqft [140m^2]







Shear Monolithic Connection between Beam and Slab

Reinforced Ridge Beams for Quad-Deck

ICF Panel Eave Detail

Alternative Eave Design

- When EPS foam and OSB nail base are used to increase thermal resistance for an ICF roof/vaulted ceiling, this can be used to construct the eave.
- The concrete portion of the ICF assembly would stop at the exterior wall while the EPS foam assembly would extend past the exterior wall in order to function as the eave.

Hybrid ICF Block – Reducing Labor by 50%

- Development of 1’x8’, 2’x8’ and 4,x8’ sized ICF blocks with four-way reversible technology, “T” and corner forms, all requiring no assembly on site would allow for achieving 150-200 sqft/man hour.
- This increase in productivity from ~35 sqft/man hour to as high as 200 sqft/man hour is essential in order to maintain competitiveness of the ICF block industry with the ICF panel industry that can currently achieve 150 sqft/man hour.
- Reducing labor costs by over 50% via larger ICF blocks, experienced ICF crews, strategic design of structures, and state-of-the-art construction management including innovative bracing and shoring, offsets the 4-12% higher costs associated with ICF materials and ads substantial value.

Decorative Concrete Floors & Countertops

- The use of decorative concrete for floors and countertops can substantially reduce building costs while providing similar quality as that of marble floors and granite countertops.
- For experienced ICF crews, labor costs would be minimal since ICF panel technologies are already being used for the ZNE-PHMH structures.
- The ICF panel technology will be integrated with tubing for radiant floor heating and cooling throughout the structure, connecting the suspended floors with both exterior and interior walls, thus leveraging the thermal mass of concrete and water.

Decorative Concrete Floors

Decorative Concrete Countertops

Concrete Countertops

- Relatively low-cost substitute vs. corian and granite
- Much higher quality than laminate
- Materials are low-cost
- Concrete coloring and design allow for very attractive floors and countertops and very competitive pricing
- Sinks can be constructed with concrete and integrated with kitchen and bathroom countertops
- Drop-in and undermount sinks

Pour in Place with PVC Edging

- There are significant economic advantages for pouring in place using PVC edging forms that also serve as guides for screeting to provide a level and flat surface.
- This eliminates grinding, moving, and transporting heavy concrete countertops.
- The following photos of pour in place concrete countertops use a variety of edging form styles, coloring, and dyes from Z Counterform Concrete Countertop Solutions .

Zero Net Energy (ZNE) Strategy

- Extensive modeling and simulation using NREL's BEopt software platform reveals that the cost in building materials and labor to achieve 100% ZNE through the envelope of a passive structure does not currently result in an appealing modified internal rate of return (MIRR).
- With the 80% drop in the prices of solar panel technology over the last five years and an additional 30% additional drop expected in the next two to three years, the most appealing strategy for achieving ZNE is targeting about 85-95% energy efficiency of the envelope and then use passive solar PV and solar thermal technologies to bridge the gap.
- There are some very innovative solar PV/T technologies currently being developed that will further enhance the cost effectiveness of solar technology in conjunction with state-of-the-art energy storage technologies, hybrid AC-DC microgrids, direct DC LED lights, direct DC appliances and consumer electronics, and GSHP-ERV-ground to air heat exchanger technologies for continuous concrete structures that incorporate hydronic-radiant heating and cooling.

Sustainable Solar Energy Technology

- The ability to economically produce and store direct current (DC) solar energy is revolutionizing the renewable energy industry.
- Solar energy is now more efficient than conventional coal or natural gas power generation technologies.
- *Recent breakthroughs in solar technology suggests self-sufficiency may become realistic in a few short years.*

Solar Technology Advances

- **Airlight Energy**, a Swiss supplier of solar technology, is working with IBM to perfect a 10-meter-high solar "sunflower." A 40-square-meter parabolic dish made of a patented "fiber-based concrete" concentrates the sun's radiation 2,000 times onto photovoltaic panels, converting 80% into 12 Kw of electricity and 20 Kw of heat. In theory, the system can also be customized to provide drinkable water, air conditioning or desalination from its hot water output.
- **SunEdison** has announced a production breakthrough that can slash the cost of the high-purity polysilicon used for solar panels. Called “high pressure fluidized bed reactor” (HP-FBR), the method is reportedly 10 times more efficient while using 90% less energy. If it is adopted at scale, it could make solar power the lowest cost way to generate electricity. See the release below for more details. *Proprietary technology will contribute to 400 watt / $0.40 per watt peak solar panel by 2016.*

Integration of Solar Parabola Concentrated Collectors & Stirling Engine Technologies

- There are currently several solar parabola concentrated collector technologies that have been integrated with stirling engine technologies to provide very efficient solar energy. Subject to validation, the manufacturers/inventors of this integrated approach claim that the solar energy produced can substantially exceed that of conventional solar PV panel production.
- A **Stirling engine** is a heat engine that operates by cyclic compression and expansion of air or other gas (the *working fluid*) at different temperatures, such that there is a net conversion of heat energy to mechanical work. More specifically, a closed-cycle regenerative heat engine with a permanently gaseous working fluid. *Closed-cycle*, in this context, means a thermodynamic system in which the working fluid is permanently contained within the system, and *regenerative* describes the use of a specific type of internal heat exchanger and thermal store, known as the *regenerator*. The inclusion of a regenerator differentiates the Stirling engine from other closed cycle hot air engines.

Consumer Electronics & Small Appliances

- According to the Energy Information Agency (EIA), the fastest growing portion of residential electricity use is consumer electronics and small appliances. In 1993, the EIA did not even bother to measure the consumption in either category; eight years later it counted over a dozen types of devices that fit in this category. By 2013, when a group of IEEE members audited their houses to get a snapshot of what they had, the list of categories expanded to over 50 small appliances and consumer electronic devices.
- These devices primarily run on DC power. Even with improvements in power supplies, many of these devices have a conversion efficiency of no better than 80% and some low-end devices have efficiencies as low as 65% in converting power.
- Such devices now account for between 15-30% of a residence's consumption, depending on demographics, country and weather zone.

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems)

Conversion & Transmission Losses

- In terms of electricity used, in 2012 the average U.S. home consumed 11,252 Kilowatt-hours (kWh). Assuming the average home used 20% of electricity for these devices, that translates into 2,250 kWh consumed by each residence. With an average efficiency of power conversion of 75%, that means 562 kWh were lost in power conversion in an average home.
- If this were the only loss from power conversion, it might be ignored, but this is not the case. On the production side of the equation, residential photovoltaic systems are coming into wider use, producing DC power that also involves significant losses. The smallest PV system typically installed has a capacity of about 1 kilowatt (KW) and produces 5,250 kWh annually.

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems**)**

Over 46% Solar DC-AC-DC Energy Conversion Loss via Net-Metering Systems

- According to the National Renewable Energy Lab's (NREL) PVWatts tool, the losses associated with converting DC to AC in a typical system comes to 23%, or 241 kWh. The average size installed is 5 KW, so the annual conversion loss amounts to 1,200 kWh for the average system.
- Then there are electric vehicles, a third major DC element. According to GM, the Chevy Volt needs to have 10.4 kWh fed into the battery for a full charge. Because of losses and battery conditioning, doing that actually requires 12.9 kWh of electricity. Assuming the Volt is driven the 35-miles-a-day national average, which is roughly the number of miles the car gets per charge, it will consume 4,700 kWh of electricity per year, of which 912 kWh is lost in conversion and charging the batteries.

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems)

DC-to-AC Derate Factor

- The PVWatts calculator multiplies the nameplate DC power rating by an overall DC-to-AC derate factor to determine the AC power rating at standard testing conditions (STC).
- The overall DC-to-AC derate factor accounts for losses from the DC nameplate power rating and it is the mathematical product of the derate factors for the components of the PV system.
- The default component derate factors used by the PVWatts calculator and their ranges are listed in the following table.

Derate Factors for AC Power Rating at STC

Component Derate Factors	PVWatts Default	Range
PV module nameplate DC rating	0.95	0.80–1.05
Inverter and transformer	0.92	0.88–0.98
Mismatch	0.98	0.97–0.995
Diodes and connections	0.995	0.99–0.997
DC wiring	0.98	0.97–0.99
AC wiring	0.99	0.98–0.993
Soiling	0.95	0.30–0.995
System availability	0.98	0.00–0.995
Shading	1.00	0.00–1.00
Sun-tracking	1.00	0.95–1.00
Age	1.00	0.70–1.00
Overall DC-to-AC derate factor	0.77	0.09999–0.96001

PVWatts Default Values

- The overall DC-to-AC derate factor is calculated by multiplying the component derate factors.
- For the PVWatts default values:
  - Overall DC to AC derate factor
    - = 0.95 x 0.92 x 0.98 x 0.995 x 0.98 x 0.99 x 0.95 x 0.98 x 1.00 x 1.00 x 1.00
    - = 0.77
- The value of 0.77 means that the AC power rating at STC is 77% of the nameplate DC power rating.
- For DC-AC-DC net-metering conversions, between 43-58% of the total energy losses for central distribution (bi-directional inverters and transformers, mismatch, AC wiring, AC central grid transmission and distribution losses) can be avoided via installation of a solar PV/T system and a hybrid AC-DC microgrid (including the use of DC powered LED lighting, DC appliances, and a DC-DC converter).

Over 70% Reduction in Energy Consumption

- If current trends continue, more renewables, electric vehicles and consumer electronics will be installed, leading to growing conversion losses. Today, a home with photovoltaic and electric vehicles will see conversion losses of 2,674 kWh annually on a consumption of 15,952 kWh, or 16%. This means more electricity is lost within the home than in delivering that home's power across the distribution and transmission grids.
- For zero net energy homes that strategically implement hybrid AC-DC distribution for solar PV systems, total energy consumption can be reduced by well over 70% via passive house design, hybrid AC-DC microgrids, DC appliances, DC powered LED lighting, alternative energy HVAC technology (including radiant floor heating and cooling), installation of state-of-the-art battery storage, and a state-of-the-art home energy management system.

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems)

Direct DC Motivating Factors

- Interest in ‘direct-DC’ power distribution is motivated by a combination of factors:
    - the exploding increase in residential and commercial photovoltaic (PV) power systems in the United States;
    - the rapid expansion in the current and expected future use of energy efficient consumer electronics products (comprised of semi-conductors) that utilize DC power;
    - the demonstrated energy savings of direct-DC in commercial data centers;
    - and the current emergence of direct-DC power standards and products designed for grid-connected residential and commercial products.

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems)

Mature Off-Grid Markets for DC Appliances

- DC appliances have served niche markets for decades, offering proof of their capacity to deliver energy services for all major electricity end-uses.
- Markets for stationary applications include off-grid residential, telecom, remote scientific monitoring stations, and emergency shelters. The products are designed to be energy efficient because of the high cost of supplying electricity to these generally remote locations.
- Mobile applications include rail, marine, and road transportation (trucks, recreational vehicles, and automobiles) and are designed to be rugged (vibration-resistant) as well as efficient. These DC appliances tend to be higher priced (per unit of service) and smaller (in the case of large appliances) than their mainstream counterparts, but their fundamental designs are applicable to mainstream use, and prices would come down with mass production.

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems)

DC-Compatible Electricity End-Uses

- Large energy savings are possible from switching from AC appliances to DC-compatible appliances, even if they are running on AC. All of the 32 electricity end-uses investigated in the LBNL report were found to be DC-compatible; indeed DC-based design increases the efficiency of all major residential and small commercial end-uses, including cooling, lighting, space and water heating, clothes washing, and dishwashing. DC is essential for all electronics.
- Key DC-based technologies include electronic lighting (fluorescent and solid state) and DC motors (driving fans, pumps, compressors and other devices, particularly ECM variable-speed operation where appropriate).

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems)

Over 40% Increase in Energy Conservation

- An increasing fraction of the residential and commercial load is DC-internal, increasing the logic of DC power use in buildings. The LBNL estimates that 33% of residential electricity use could be saved by converting all appliances to high-efficiency, DC-internal technology running on AC.
- Direct-DC power systems could offer additional savings by eliminating the AC-to-DC conversion losses, which constitute on average 14% of the AC load. Note however that, if grid backup power is used (instead of DC battery backup power) to supply DC loads, AC-to-DC conversion losses will reduce the net savings to less than 14%. Savings should be higher for the commercial sector because of the greater coincidence with insolation and load, particularly for space cooling.

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems)

Dominant AC Electricity End-uses in the US

Table 1. Dominant AC electricity end-uses in the U.S. residential and commercial sectors showing energy use (quads) in 2010 and electricity usage rankings.

End Use	Residential (quads)	Ranking	% of sectoral total	Commercial (quads)	Ranking	% of sectoral total
Cooling	0.79	1	16%	0.5	3	11%
Lighting	0.72	2	15%	1.12	1	24%
Refrigeration	0.45	3	9%	0.23	5	5%
Sub-total	1.96		40%	1.85		39%
US Total	4.95			4.73		
Subtotal as percent of total	40%			39%		

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems)

24VDC Occupied Space Standard

- While EVs and plug in hybrid EVs (PHEVs) are creating new DC demand, other products are entering the market to distribute DC power directly to appliances, which in turn is stimulating a new market in DC appliances.
- The EMerge Alliance, an industry alliance promoting the use of direct-DC, is registering products that are designed to meet its new 24VDC Occupied Space Standard. Notable is the Armstrong Ceiling, which integrates the 24VDC bus into the metal framework that traditionally holds the tiles in a commercial drop ceiling. With this product, 24VDC appliances and controls can be easily installed and relocated without the need of an electrician. Nextek Power Systems has produced DC lighting and fans, while Lunera, Focal Point, and Cooper have all produced 24V luminaires, to couple to the EMerge ceiling.

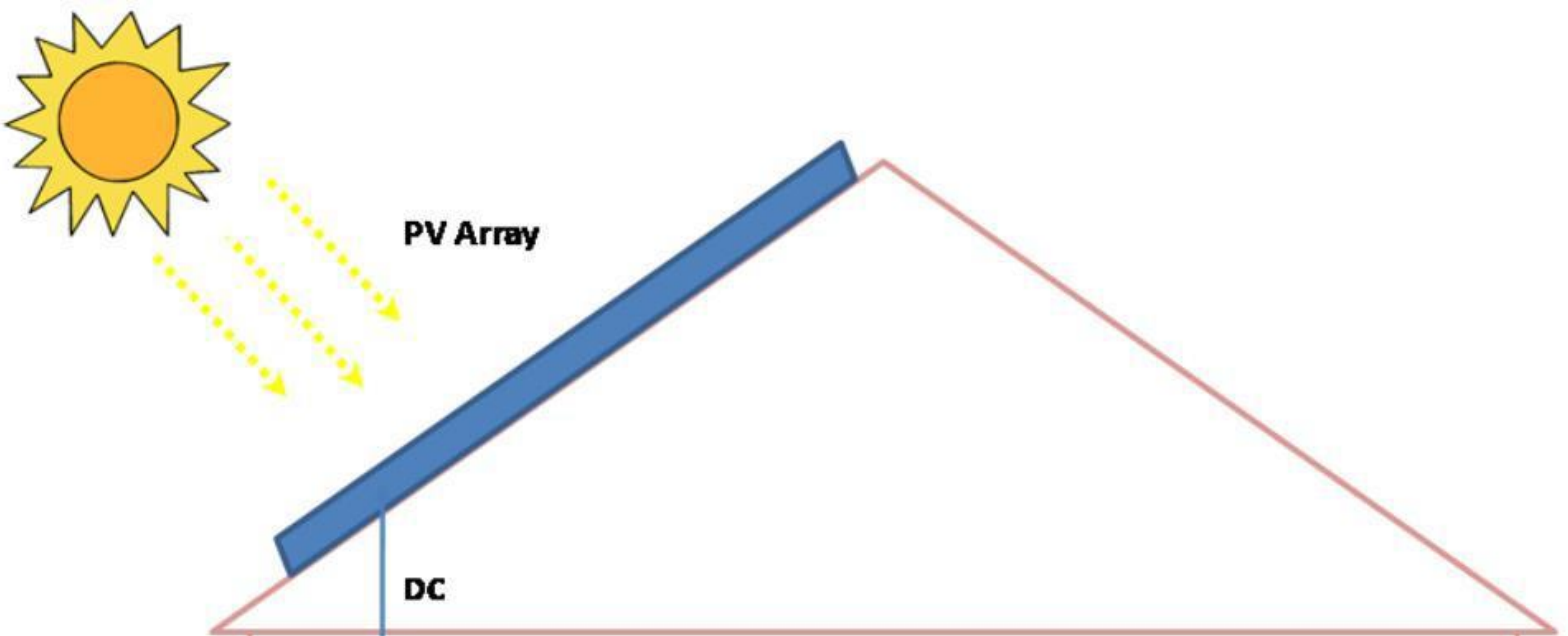
(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems)

New PoE & 380VDC Standards

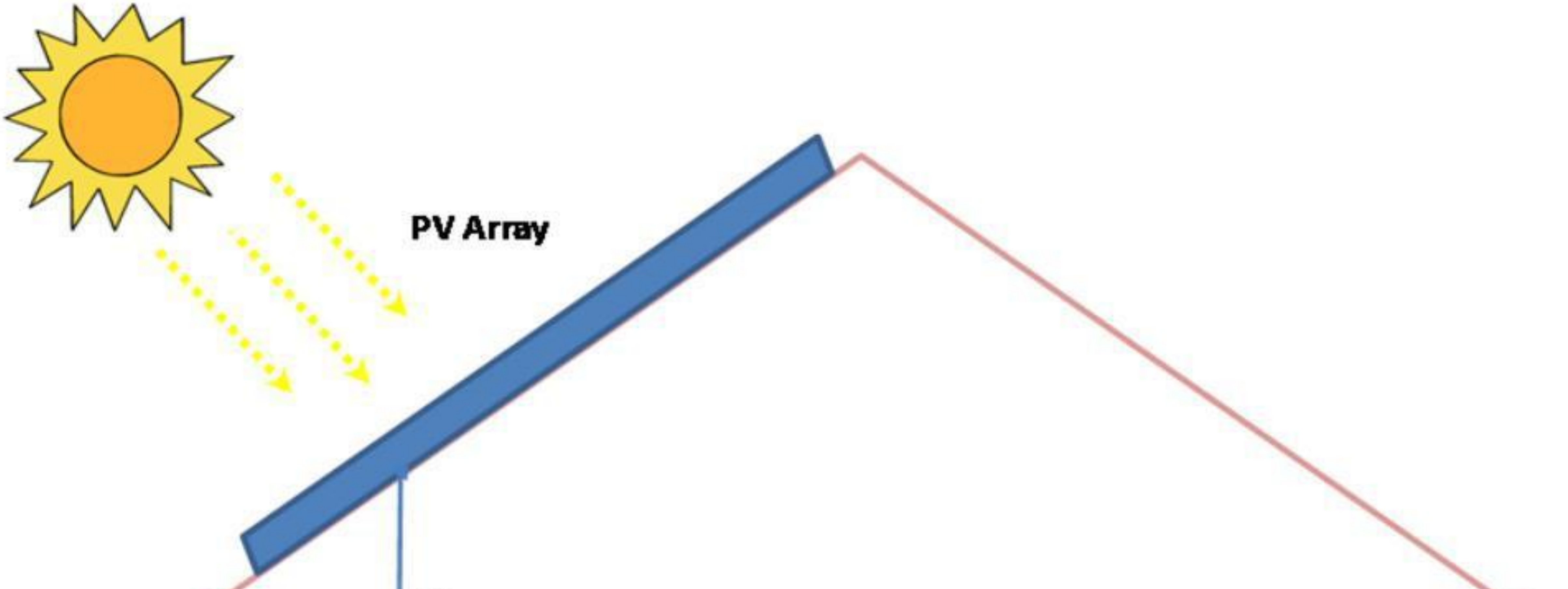
- Power over Ethernet (PoE) is another rapidly expanding low voltage DC distribution system. PoE standards are evolving to accommodate higher power devices. The Institute of Electrical and Electronics Engineers (IEEE) has revised the PoE standard (IEEE802.3) rapidly upward from 15.4W in 2003, to 25W in 2009 (both at 48VDC).
- The Institute is currently developing a new standard that is expected to extend that limit to 65W at 51-54VDC, offering the opportunity to power an expanding universe of consumer electronics. While the current EMerge system and PoE cannot power large appliances, EMerge is now developing a 380VDC standard to meet large loads in data centers and telecom central offices. Together, the two standards provide a foundation for serving all residential and commercial loads.

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems)

AC Power System with Storage. Simple schematic of building with a net-metered PV system, electricity storage and an optional electric vehicle load. The inverter is bi-directional, allowing battery charging from the solar system during the day and from the grid at night.

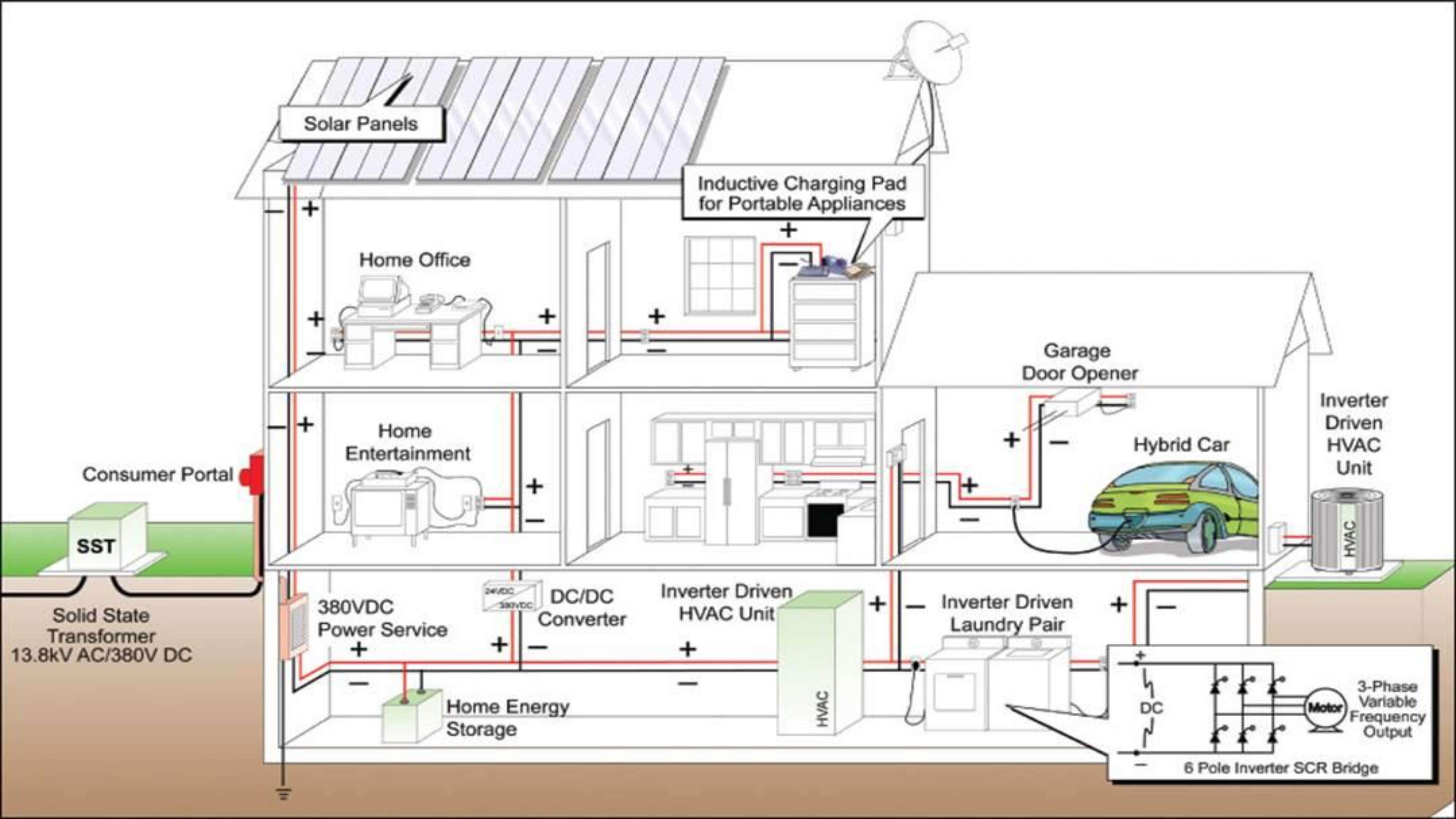


DC Power System with Storage. The loads in the building are the same as in Figure 4 above, except for the AC/DC power supplies. Power is distributed at 380VDC for high power loads and at 24VDC for low power loads.



Hybrid AC-DC Residential Systems

- Since a portion of the home will continue to use AC for dryers, microwave, hair dryers, toasters, possibly also for washers, freezers and refrigerators until the pricing of DC appliances decreases with demand, a hybrid AC-DC wiring system could provide an alternative solution that adds considerable value for residential applications.
- Yet another alternative would be to use DC-DC & DC-AC converters for a 24V DC low voltage delivery integrated with 380V DC distribution systems (refer to the following illustration).

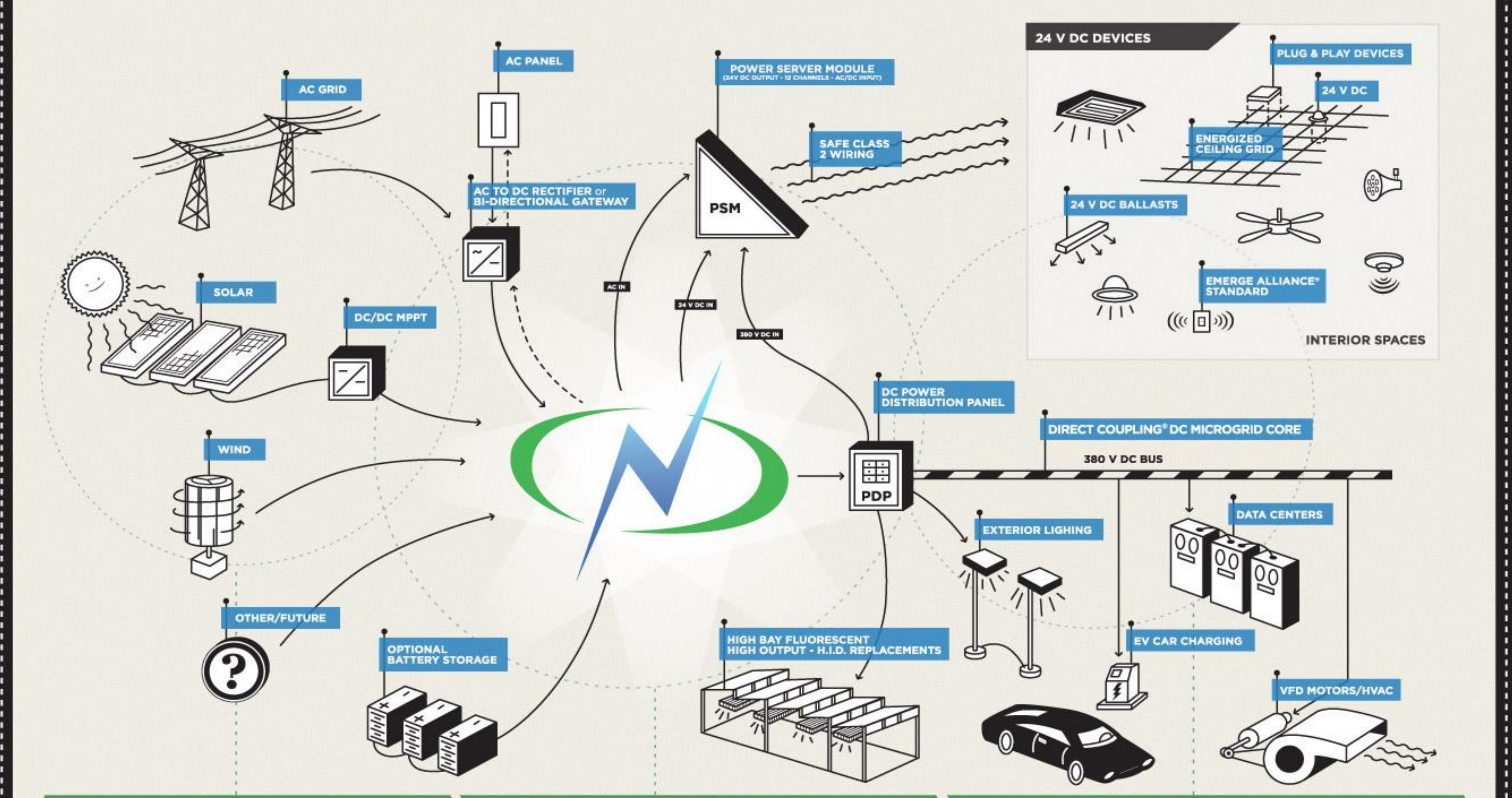


Solar Panels
Inductive Charging Pad for Portable Appliances
Home Office
Home Entertainment
Consumer Portal
SST
Solid State Transformer 13.8kV AC/380V DC
380VDC Power Service
DC/DC Converter
24VDC
380VDC
Inverter Driven HVAC Unit
HVAC
Home Energy Storage
Garage Door Opener
Hybrid Car
Inverter Driven HVAC Unit
Inverter Driven Laundry Pair
DC
Motor
3-Phase Variable Frequency Output
6 Pole Inverter SCR Bridge

Advanced Energy Storage (AES)

- Smart homes require state-of-the-art energy storage technologies for DC distribution systems that are independent of the grid. This allows for optimizing energy efficiency by minimizing thermal energy losses resulting from converting DC-AC-DC via net-metering programs.
- DOE research led by the Argonne National Lab is exceeding lithium ion battery performance and capacity while reducing costs via the Joint Center for Energy Storage Research (JCESR).
- This AES technology will be available for use in both electric and hybrid vehicles, and also in modern DC distributive systems, e.g., DC microgrids for use in smart homes, by 2021.

HOW DOES A DC MICROGRID WORK?



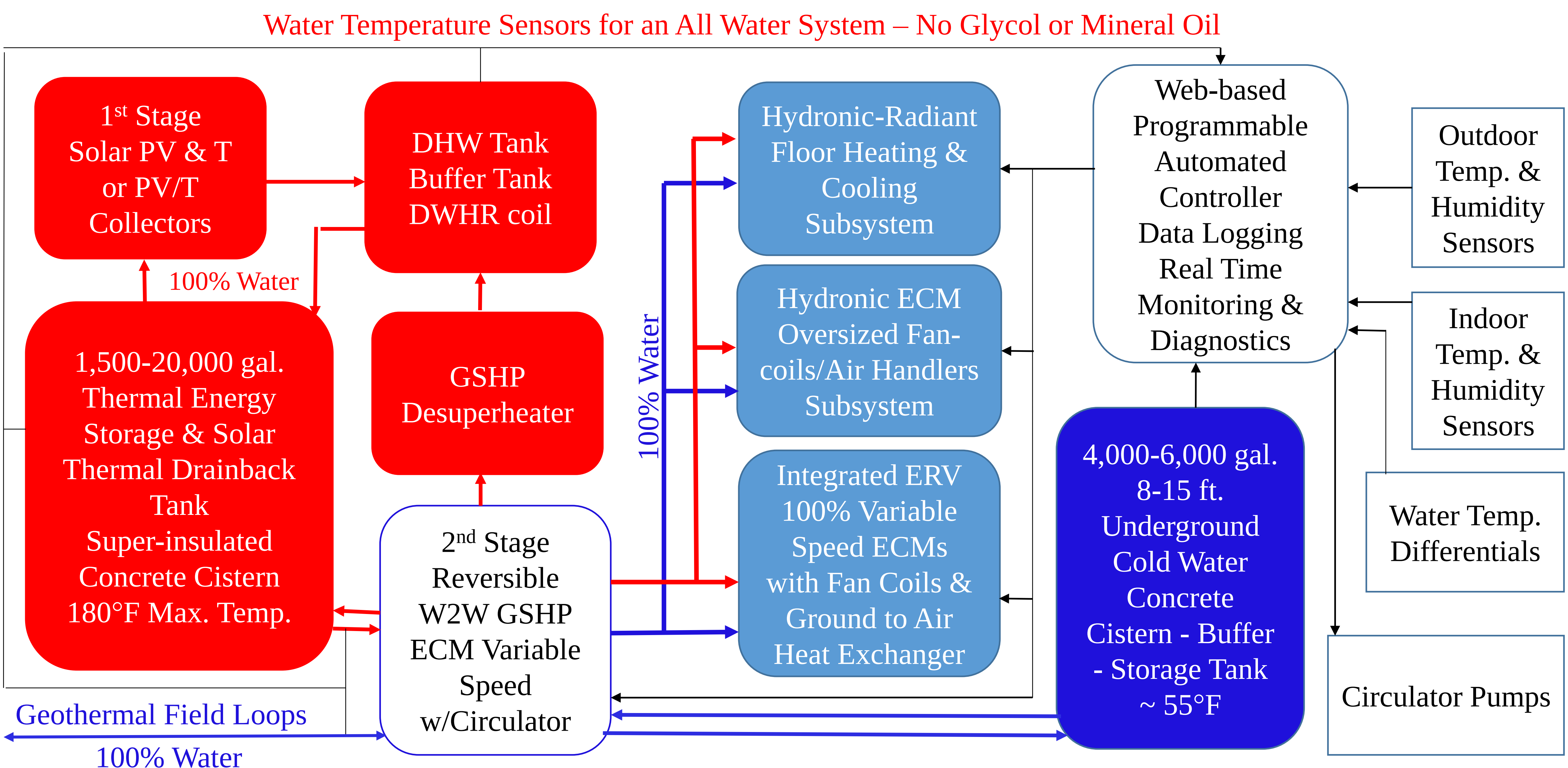
Strategic Battery Storage Design

- When a DC battery storage system is included in a solar PV system, optimal energy efficiency can be attained.
- Since large battery systems are expensive, especially for current lithium ion technology (similar to that used in current electric vehicles), 12-24 hr. battery systems can be strategically designed to fill the gap for provision of DC power during evenings when the sun is not shining, then be re-charged during the day.
- An initiative at the Argonne National Laboratory is underway to increase battery capacity by five fold while reducing costs by 50% within five years. This technology should be commercially available by 2021.

Optimizing Energy Efficiency for HVAC

- For an all water solar thermal and integrated water to water GSHP system, there is no concern for separation of fluids (glycol and water).
- Thus, brazen plate heat exchangers are not necessary and the use of coils can be minimized. This reduces installation costs and head loss for circulation pumps.
- Solar thermal water can still be inserted directly into the GSHP via a three way valve, and/or merely circulated into an insulated buffer tank/thermal battery system. The resulting savings can then be invested in additional solar thermal panels.
- A variable ECM GSHP with a brazen plate heat exchanger and variable ECM circulator pump can be utilized to optimize energy efficiency for geothermal loops.

Integrated HVAC System Flow Chart



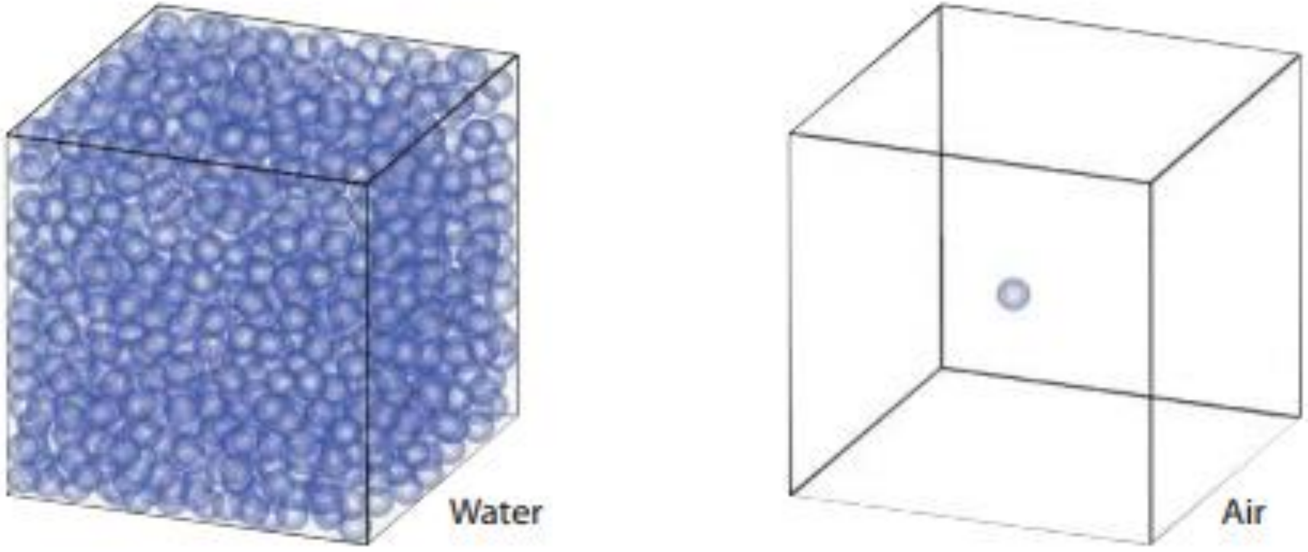
Energy Efficiency of Air vs. Water Transport

- For a given temperature rise, liquid water can absorb and distribute ~3,500 times more heat than the same volume of air. Hence, water is substantially more efficient than air as a means of transporting thermal energy.
- A ¾” water pipe can move as much energy as an 18” diameter circular air duct or a 20” x 12” rectangular duct.
- Additionally, in terms of wattage usage, water pumps are 90% more efficient than fan motors for transporting thermal energy.
- In contrast to forced air systems, hydronic-radiant systems allow for more efficiently establishing strategic living area set-points, thus further enhancing HVAC efficiency via zoning.

Density of Water vs. Air

Water is 832 times denser than air.

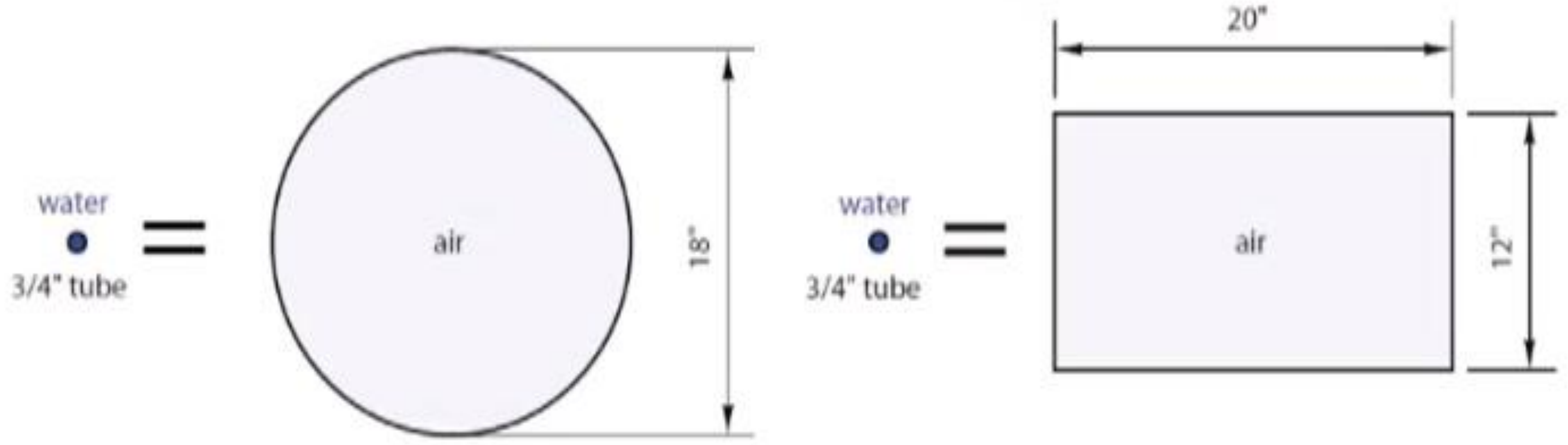
That means water can capture and channel more energy per unit volume than air.



Source: Thermally Active Surfaces in Architecture, K.Moe, Princeton Architectural Press © 2010

Efficiency: Energy Consumption

Material	Specific Heat Btu/lb/°F	Density lb/ft³	Heat Capacity Btu/ft³/ °F
Water	1.00	62.4	62.4
Air	0.24	0.0074	0.018



tekmar®

Modern Hydronic Technology

- Nearly all geothermal heat pump systems can be enhanced through modern hydronic technology. Techniques such as:
  - state-of-the-art geoexchange loop fields (including hydrated sand baths)
  - hydraulic separation & manifold based distribution systems
  - zoning, synchronization, and cool air flush during summer months
  - thermal battery/storage systems
  - variable-speed ECM circulators and consolidation of supply and distribution loops
  - radiant floor heating and cooling & 2^{nd} stage fan-coil/air handlers
  - integration with solar thermal collectors, ERVs, and ground to air heat exchangers
  - using all water for solar thermal drainback, thermal battery & GSHP systems
  - web-based programmable controls for integrated systems

can all be successfully applied in combination with geothermal or ground source heat pumps (GSHPs) to provide unprecedented energy efficiencies for integrated systems.

Providing Domestic Hot Water Coils & Supplementing GSHPs via Solar Energy

- Due to heat loss of thermal storage systems such as thermal batteries, the most efficient use of solar thermal energy is achieved through direct use.
- Hence, heating domestic hot water (DHW) and supplementing the supply side of a water to water GSHP in the heating mode are the most efficient use of solar thermal resources and should be priorities for designing integrated systems.
- All water systems are compatible with this approach to optimizing efficiency of solar thermal energy.

Integration of Solar PV & Solar Thermal

- Solar PV systems can range from 20-45% conversion efficiency.
- The majority of solar PV technologies range from 15-22% conversion efficiency.
- This reveals that 55-85% of the energy produced by solar PV panels is thermal energy.
- As the temperature rises, solar PV conversion efficiency drops due to resistance which results in production of thermal energy.
- Hence, there is potential to simultaneously maintain solar PV conversion efficiency while capturing the associated thermal energy.

State-of-the-Art W2W GSHP Technology

- With water to water (W2W) ground source heat pump (GSHP) technology advances using electrically commutated motors (ECM) and 100% variable operation, coefficients of performance (COP) can now range over 7.0 (over a 700% increase in energy efficiency compared with conventional HVAC technologies) for properly designed systems.
- This is particularly true for integration of W2W GSHPs and Desuperheaters with solar PV/T systems that provide DC power and solar hot water.
- By strategically installing geoexchanger field loops around the footings of a basement for a super-insulated passive house (which reduces peak heating and cooling loads by over 95% for ICF structures), costs of GSHP installations can be reduced by up to 50%.

Solar PV & DC Powered GSHP Systems

- One of the advantages of powering GSHP systems with solar power is eliminating the power losses for converting DC-AC-DC via net-metering systems.
- During the day when the PV system is producing DC power, this power source can be utilized directly by the GSHP and other DC powered devices.
- This is particularly true for hybrid AC-DC microgrids.

Water vs. Soil Geoexchange

- Due to physical and chemical properties, water is at least three times more efficient at exchanging thermal energy than air.
- With relative high porosity, water saturated sandy and clay soils provide good thermal conductivity and diffusivity which is ideal for optimizing performance of geothermal field loops.
- A moist clay soil or water saturated sandy soil is substantially more efficient for use with geoexchange systems than dry sandy soils.
- Water saturated (hydrated or charged) sandy soils has the potential to mimic the geoexchange rate provided by placing coils in pond water.

Porosity Ranges for Sediments

Material	Porosity (%)
well-sorted sand or gravel	25-50
sand and gravel, mixed	20-35
glacial till	10-20
silt	35-50
clay	33-60
(Based on Meinzer (1923a); Davis (1969); Cohen (1965); and MacCary and Lambert (1962) as quoted by C.W. Fetter [2])	

Sands have large pore spaces, whereas clays have many small pore spaces. Both sand and clay can have high porosity.

Thermal Conductivity and Diffusivity of Sand and Clay Soils

Thermal Conductivity (**k**) - **Btu/hr-°F-ft** and Thermal Diffusivity (α) - **ft^2/day**

Soil Type	Dry Density	5% Moist		10% Moist		15% Moist		20% Moist	
		k	α	**k**	α	**k**	α	**k**	α
Coarse 100% Sand	120 lb/ft^3	1.2-1.9	0.96-1.5	1.4-2.0	0.93-1.3	1.6-2.2	0.91-1.2	-	-
	100 lb/ft^3	0.8-1.4	0.77-1.3	1.2-1.5	0.96-1.2	1.3-1.6	0.89-1.1	1.4-1.7	0.84-1.0
	80 lb/ft^3	0.5-1.1	0.60-1.3	0.6-1.1	0.60-1.1	0.6-1.2	0.51-1.0	0.7-1.2	0.52-0.90
Fine Grain 100% Clay	120 lb/ft^3	0.6-0.8	0.48-0.64	0.6-0.8	0.4-0.53	0.8-1.1	0.46-0.63	-	-
	100 lb/ft^3	0.5-0.6	0.48-0.58	0.5-0.6	0.4-0.48	0.6-0.7	0.37-0.48	0.6-0.8	0.41-0.55
	80 lb/ft^3	0.3-0.5	0.36-0.6	0.35-0.5	0.35-0.5	0.4-0.55	0.34-0.47	0.4-0.6	0.30-0.45

Coarse grain = 0.075 to 5 mm - Fine Grain less than 0.075 mm

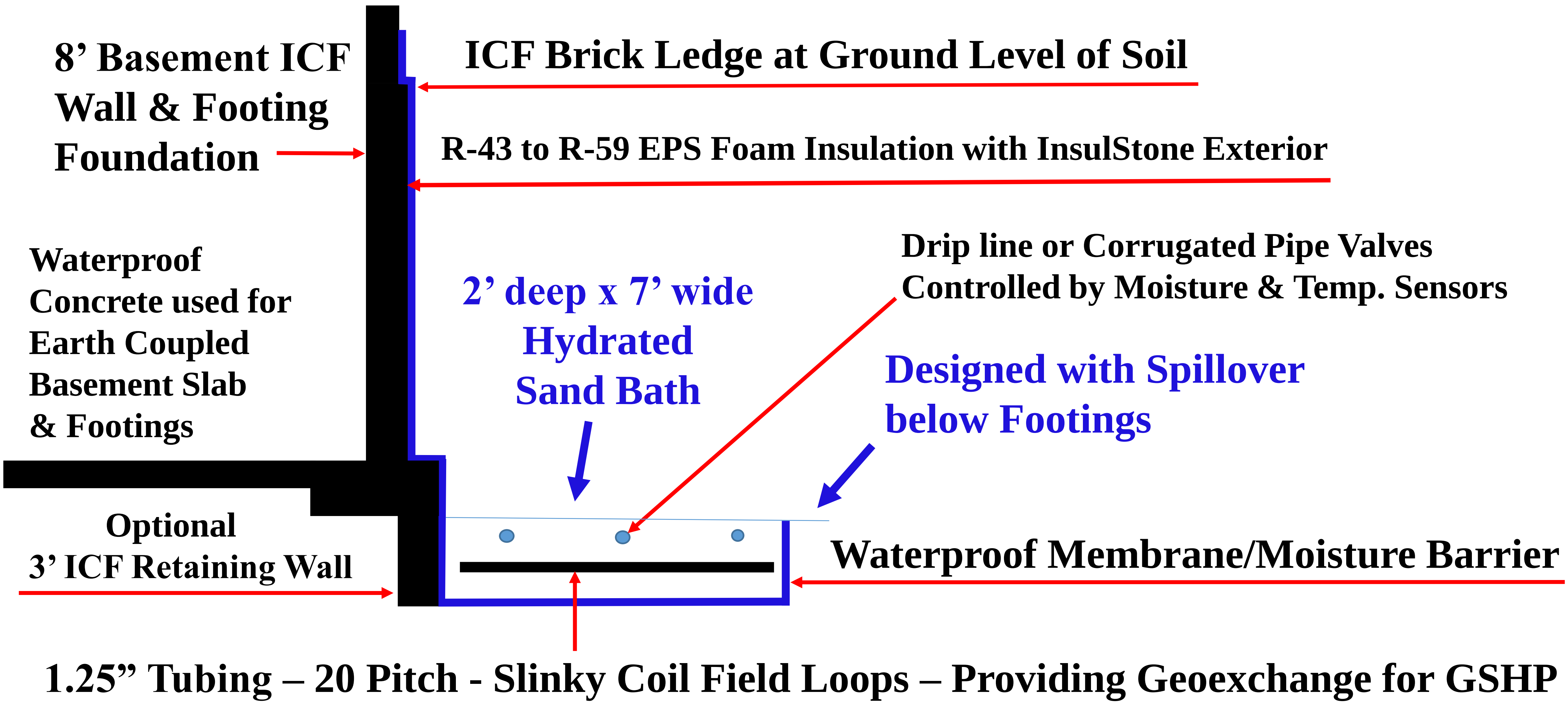
Sand Bath Field Loops

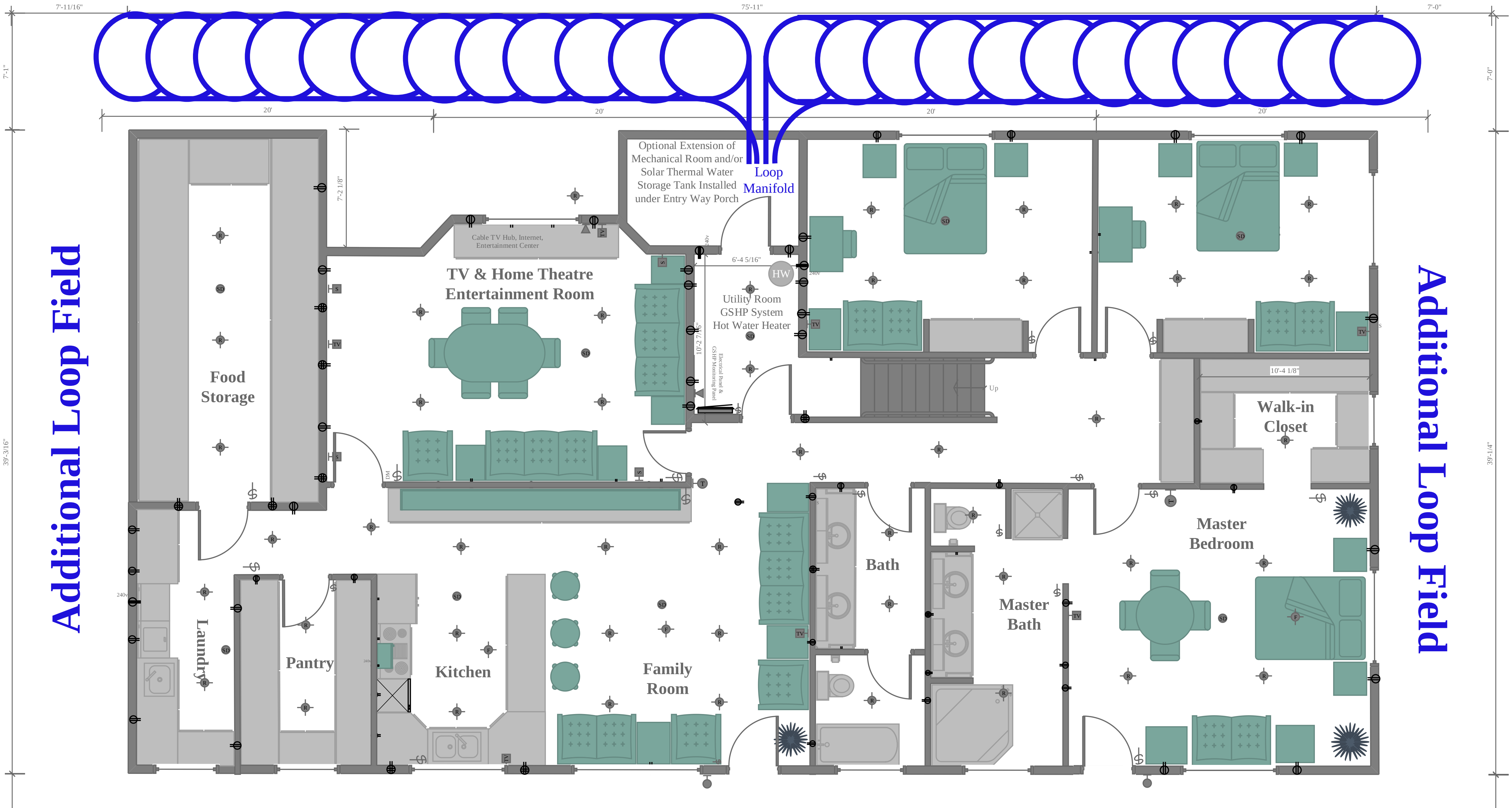
- For soils with low water holding capacity, installing slinky field loops placed in a sand bath around the footing of a structure with a moisture barrier to protect the structure provides the potential to mimic the geoexchange performance achieved from pond loops.
- This approach using a drip line and either moisture sensors in the soil or temperature sensors installed on the geoexchnage tubes (connected to an automated control that operates the drip-line valve) provides the capability of maximizing geoexchange in virtually any soil type.
- Capital investment in field loop tubing can be minimized. As little as 400’ of overlapped slinky tubing per ton of heating or cooling capacity buried 8-10’ deep should be sufficient for most applications.

Length of Slinky Loops

- Since the circumference of a circle = Pi x D (3.1416 x Diameter of 6 ft.) = 18.8496 ft. per slinky coil.
- Based on 400 ft. of heat exchange tubing required per ton of heating and cooling capacity for hydrated/charged soils, with 2 ft. overlapping coils (20’ pitch) that would require only 20 ft. of slinky coils per ton.
- These loops could be efficiently installed in 7’ wide footing trenches around the structure, thereby minimizing labor and excavation costs.
- This could result in reducing installation costs of water to water GSHPs by as much as 50%.

Sand Bath Field Loop Design





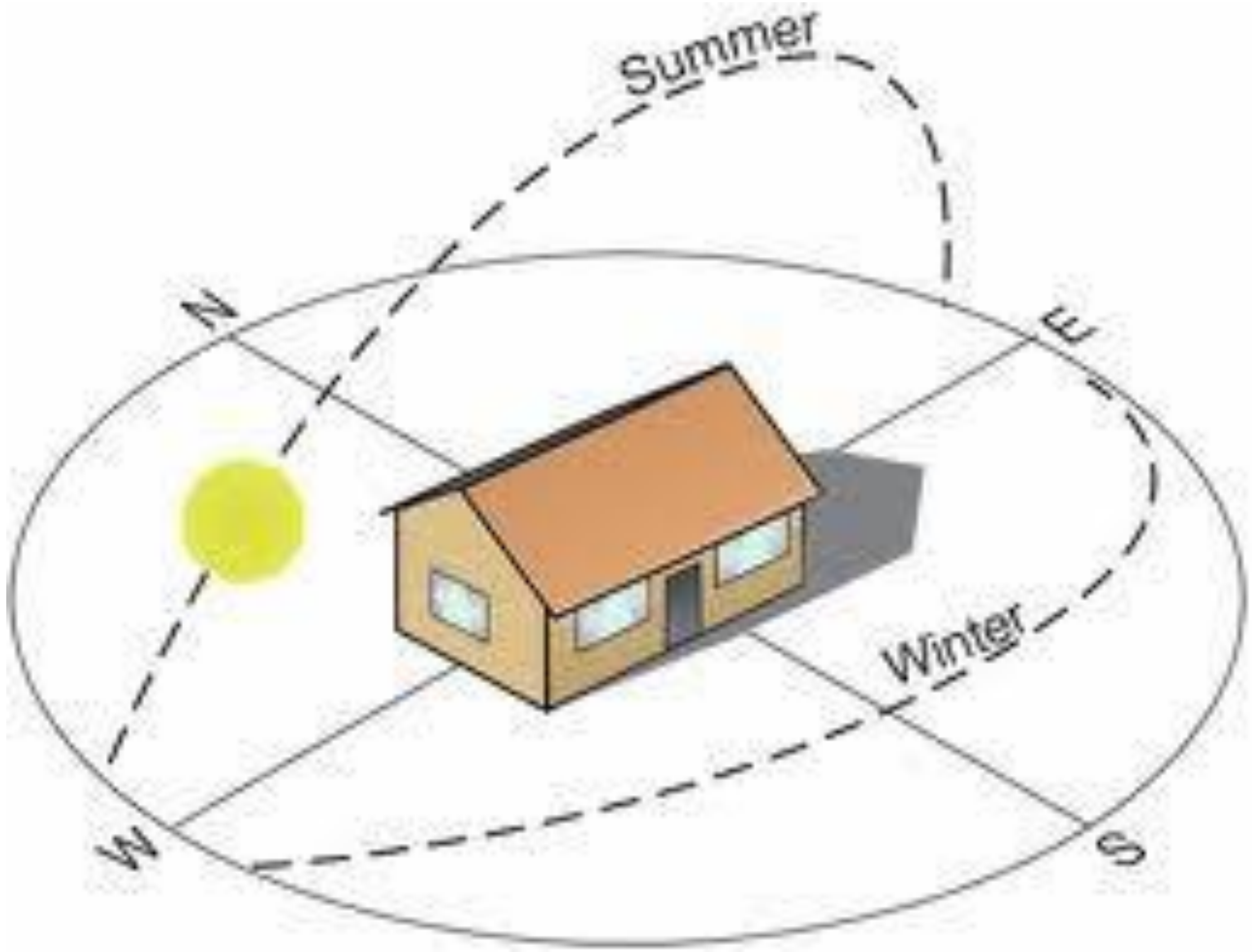
83' x 47' = 260' of trench (twelve 20' loops with 6' coils overlapped by 2') would provide enough heat exchange for well over 12 tons of heating & cooling capacity in a saturated sand bath

Calculating Overhang of Eaves for Homes ZNE-PHMHs in Boise, ID

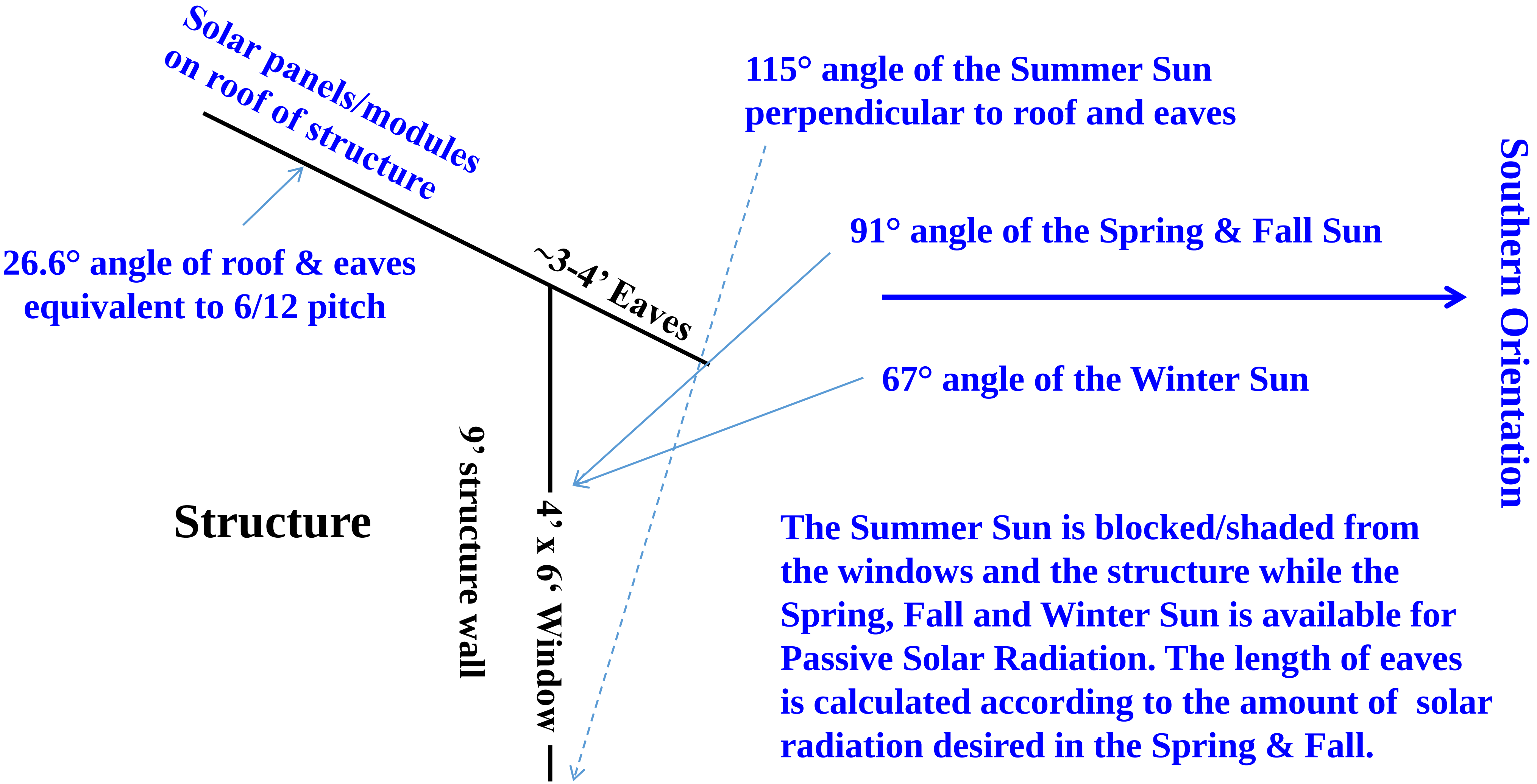
Seasonal angle of the sun - degrees from vertical:

- On the 21st December, the sun will rise 67° east of due south and set 67° west of due south.
- On the 21st March/21st September, the sun will rise 91° east of due south and set 91° west of due south.
- On the 21st June, the sun will rise 115° east of due south and set 115° west of due south.

(This information can also be used to strategically adjust PV panels and thin film PV modules for maximizing efficiency of solar power systems, particularly through solar power arrays and solar tracking systems powered by an electric motor to provide up to 45% additional yields.)


Summer
N
E
W
S
Winter

Calculating Overhang of Eaves & Pitch of Roof for Homes in Boise, ID



The Summer Sun is blocked/shaded from the windows and the structure while the Spring, Fall and Winter Sun is available for Passive Solar Radiation. The length of eaves is calculated according to the amount of solar radiation desired in the Spring & Fall.

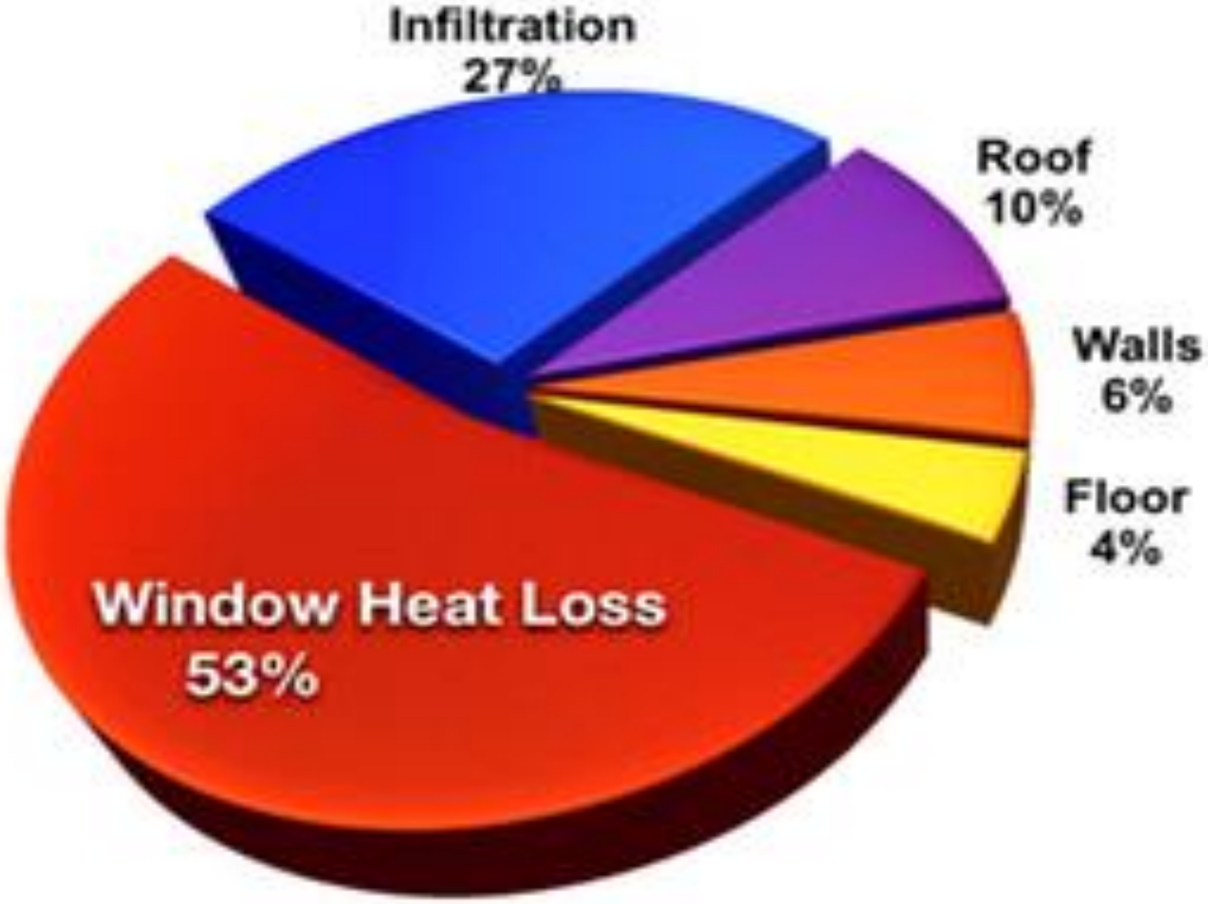
Boise, ID Latitude & Solar Thermal Angle

- The latitude in Boise, ID is 43.62 degrees
- The winter season has the least sun, so you want to make the most of it. The tilt of collectors for a passive solar system should be designed so that the panel points directly at the sun at noon. To calculate, multiply your latitude by 0.9, and add 30 degrees.
- In Boise, ID, the angle of the tilt would be 69.26 degrees. So for a 6.9/12 pitch roof at a 30 degree slope, the solar thermal racking system would require an angle of 39.26 degrees to provide the targeted 69.26 degree angle for optimizing solar thermal performance in the winter.

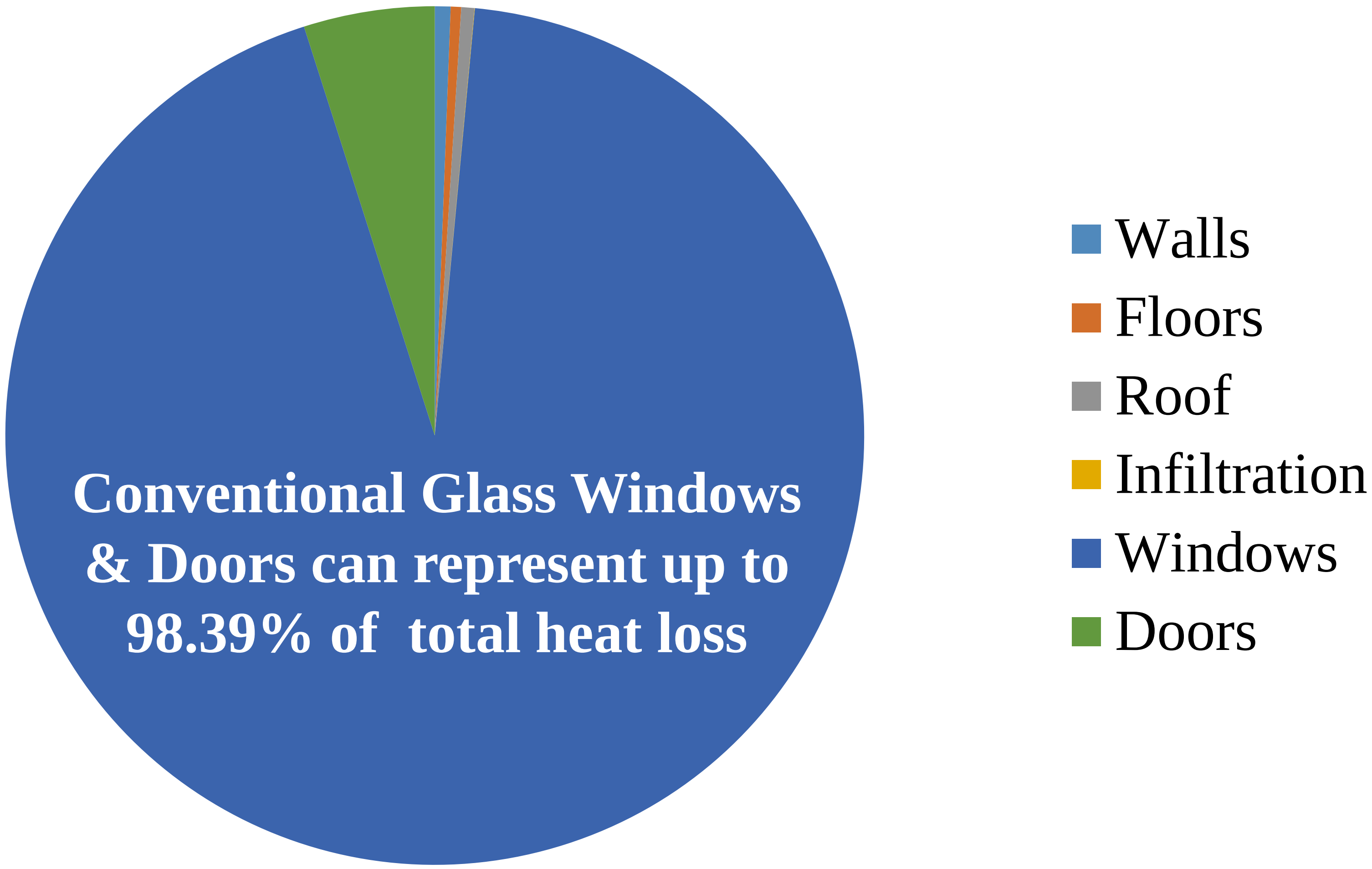
High Performance Passive Windows

- As much as 53% of the thermal energy loss in conventional homes is a result of low performance windows.
- In addition to low performing windows, improper installation, air infiltration, and thermal bridging adds to the thermal energy losses in conventional stick-frame and even ICF homes.
- For ZNE-Passive House design in which heat loss for air tight ICF envelopes and super-insulated walls and vaulted ceilings can reduce peak heating and cooling capacities by over 95%, over 90% of the resultant heat loss is through windows.

Conventional Window Heat Loss For Average Stick-frame Construction



Conventional Window & Doors Heat Loss For Air-tight Super-insulated ICF Construction



Reducing Window Heat Loss

- Efforts to achieve zero net energy homes must focus on strategies such as:
  - Strategic orientation
  - Length of eaves and pitch of roof
  - Multiple layer high performance windows and foam installation (reduce energy loss by virtually eliminating infiltration and thermal bridging)
  - Provide state-of-the-art glazing systems and exterior automated shades that enhance thermal insulation
  - Strategically balance U-factor with SHGC for specific localities and orientation of structures

Zero Energy Windows

- Energy requirements for today's typical efficient window products (i.e. ENERGY STAR™ and passive house products) are significant when compared to the needs of Zero Energy Homes (ZEHs).
- Through the use of whole house energy modeling, typical efficient products were evaluated in five US climates and compared against the requirements for ZEHs.
- Products which meet these needs are defined as a function of climate. In heating dominated climates, windows with U-factors of 0.10 Btu/hr-ft^2-F (0.57 W/m^2-K) will become energy neutral.
- In mixed heating/cooling climates a low U-factor is not as significant as the ability to modulate from high SHGCs (heating season) to low SHGCs (cooling season).

(Aresta et al, 2014. Performance Criteria for Residential Zero Energy Windows, Windows and Daylighting Group, LBNL)

Zero Energy Windows in Northern Climates

- Our approach to achieving a Zero Energy Window in northern climates is to focus on the development of dynamic windows with a high maximum SHGC (up to 0.6 SHGC). This lessens the need to reduce window U-factors to below 0.2 Btu/hr-ft^2-F (1.14 W/m^2-K) for Zero Energy Windows, from an energy perspective.
- However, another significant feature of ZEHs is the downsizing of HVAC systems which requires that peak load impacts (both winter and summer) be minimized. Such constraints may be used to argue for low U-factor dynamic windows, even if this combination exceeds the requirements for zero energy impacts. This topic of windows for ZEHs and HVAC integration requires additional research.

(Aresta et al, 2014. Performance Criteria for Residential Zero Energy Windows, Windows and Daylighting Group, LBNL)

Average Daily Total Solar Radiation for U.S. Cities

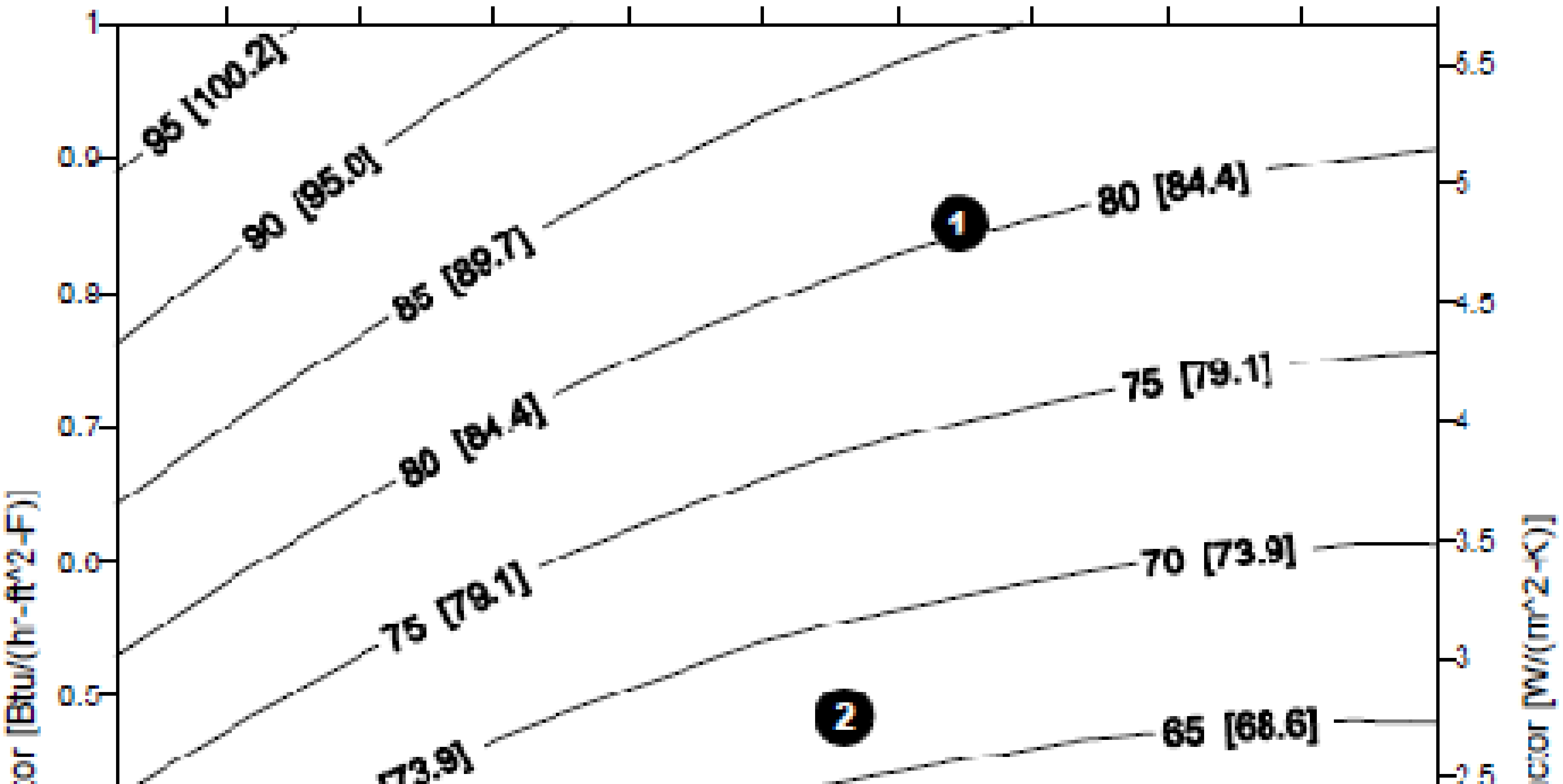
The values listed in this table are based upon TMY data for each of the cities listed. The data for the tilted surface radiation was processed using the TRNSYS 13.1 radiation processor with the Hay and Davies tilted surface radiation model.

City	$MJ/m^2 \cdot day$	$MJ/m^2 \cdot day$	$Btu/ft^2 \cdot day$	$Btu/ft^2 \cdot day$
	23° Tilt	45° Tilt	23° Tilt	45° Tilt
Albuquerque, NM	23.58	23.42	2076	2062
Apalachicola, FL	18.13	17.50	1596	1541
Atlanta, GA	16.62	16.12	1463	1420
Baltimore, MD/ DC	14.79	14.75	1302	1299
Billings, MT	15.91	16.58	1401	1460
Birmingham, AL	16.25	15.76	1431	1388
Boise, ID	17.54	17.91	1545	1578
Boston, MA	11.41	11.62	1005	1023
Burlington, VT	12.87	13.07	1134	1151
Casper, WY	18.96	19.80	1669	1743
Charleston, SC	14.91	14.73	1313	1297

Boise, ID ZNE-PHMH Project

- Though we want to showcase state-of-the-art passive house technology, depending on the homeowner's budget we will have the flexibility of designing and building homes that virtually any homeowner can afford.
- Strategic design, orientation, 3' eaves via a 6/12 pitch, and automated exterior shades will allow us to showcase dynamic window systems for zero net energy homes.
- The following illustration for a Salt Lake City residential structure is similar to the environment in Boise, ID where the first ZNE-PHMH will be built. We will be targeting U-0.08 & SHGC 0.5.

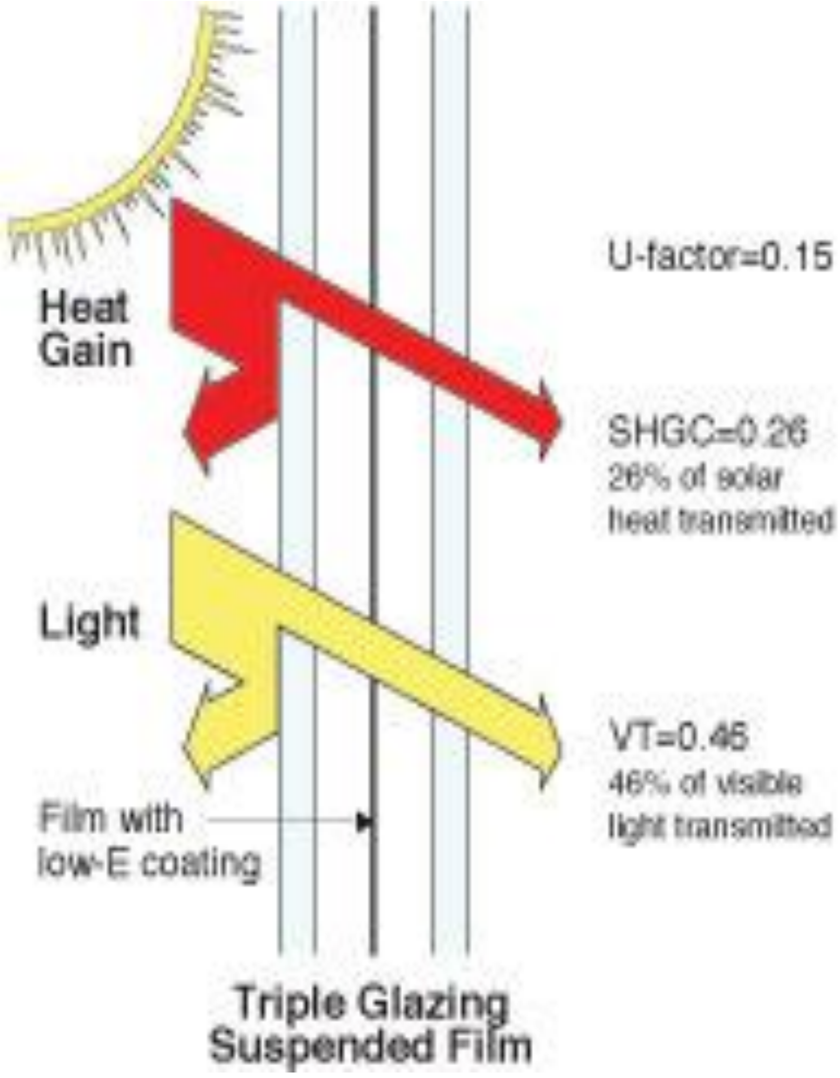
Salt Lake City, UT - Combined Annual Heating and Cooling Energy
(contours in MBtu [GJ])

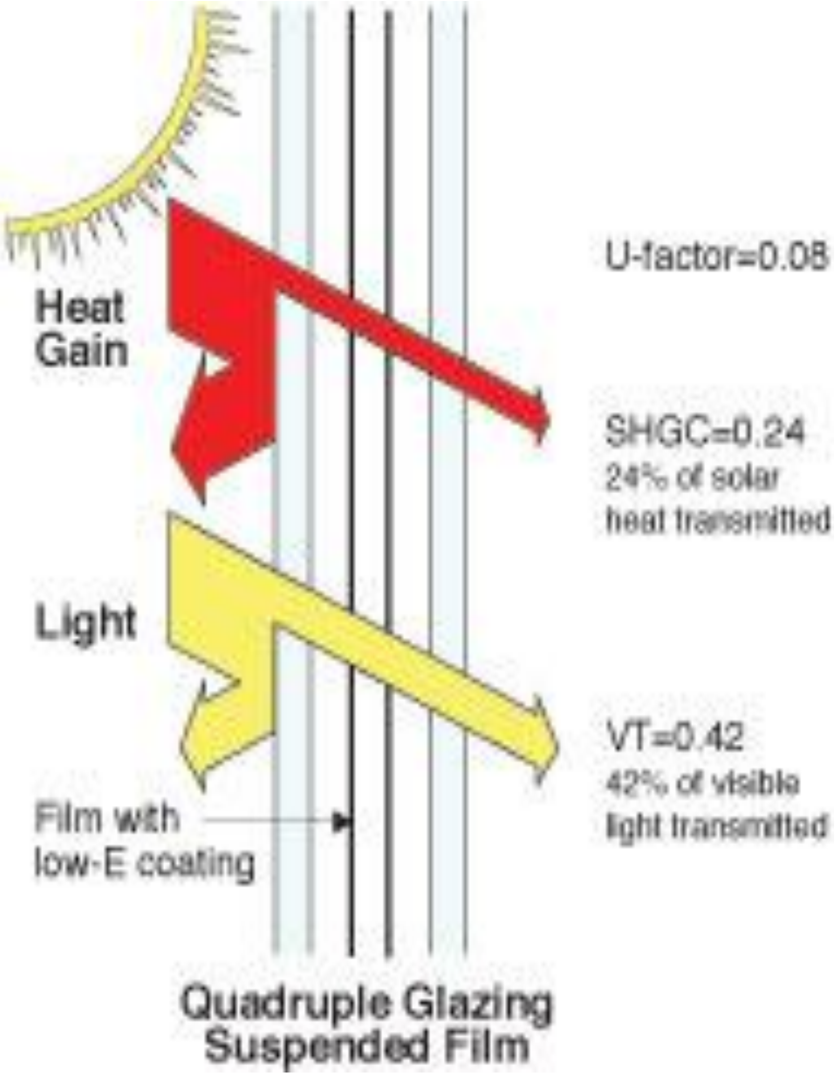


Innovative Passive Window Technology

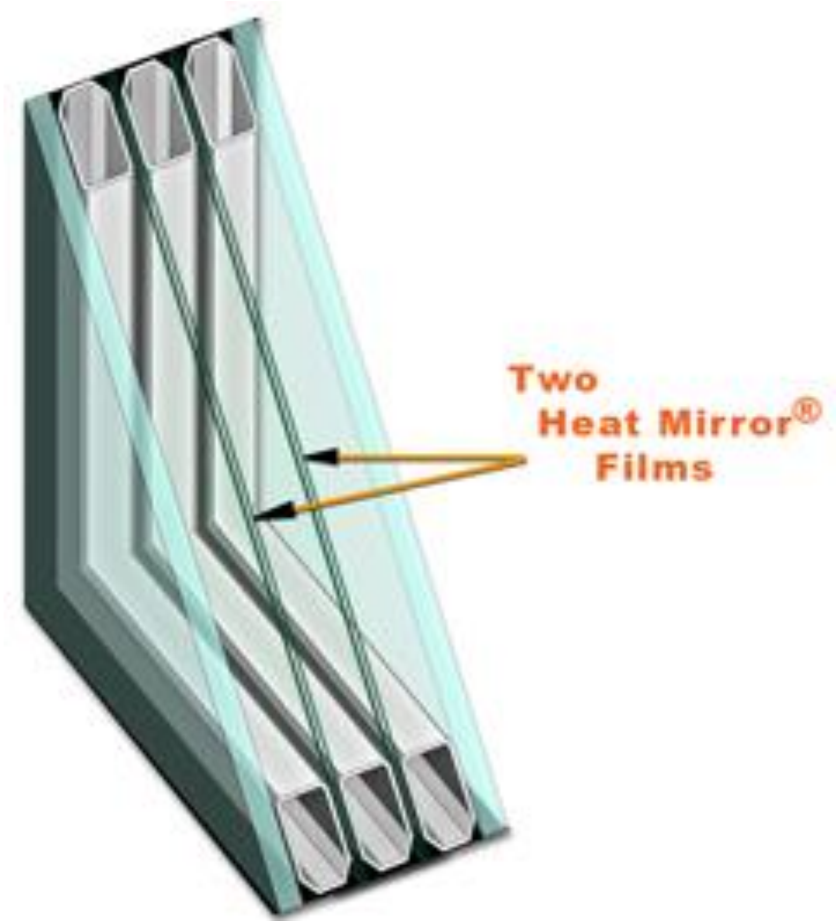
- High performance glazing systems, insulated window frames with thermal breaks, and state-of-the-art insulated glass units (IGUs) with warm edge spacers can become net-producers of thermal energy during the day.
- Balancing thermal resistance with solar heat gain and thermal mass is critical for passive structures.
- Modern glazing technology, improving thermal resistance of frames, reducing infiltration, and state-of-the-art installation using adequate foam products is required.
- Automated exterior shades and innovate low-e coatings can minimize heat loss between sunset and sunrise for glazing systems that are designed to optimize solar radiation during the day.

Multiple Pane Hybrid IGUs



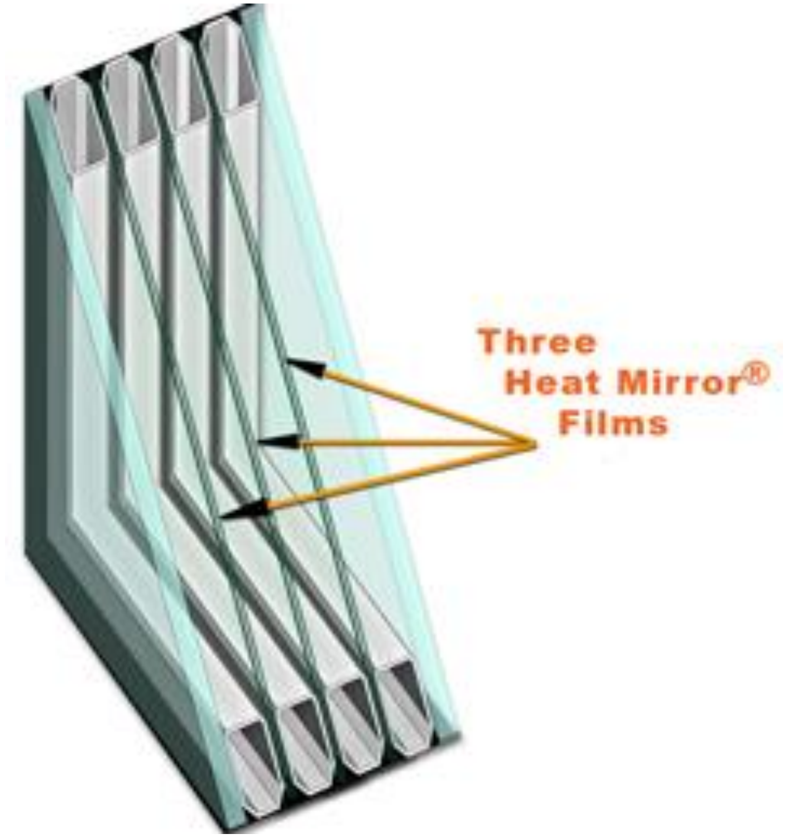


Dual HM Film Tri-cavity



A second Heat Mirror film can be added for even higher insulating performance. With an optional Krypton gas filling, dual-film/tri-cavity Heat Mirror Insulating Glass can achieve a U-value of 0.08 (R-value of 12.5). An all glass or SCF tri-cavity IGU using argon or krypton can achieve U-0.089 (R-11.23).

Tri HM Film Quad-Cavity



Heat Mirror Insulating Glass using three Heat Mirror films suspended inside of an insulating glass unit, creating four air spaces, is one of the most energy-efficient glazing products in the world. With an optional xenon gas filling, tri-film/quad-cavity Heat Mirror Insulating Glass can achieve an industry-leading U-value of 0.05 (R-value of 20). In comparison with krypton gas filling, LBNL Window 7 modeling reveals that either thicker and heavier all glass or SCF IGUs with quad cavities can achieve U-0.053 (R-18.87).

Cost Comparison
Suspended Coated Films vs. Glass

- According to Southwall Energy Technologies and Eastman Chemical Company, all glass triple pane IGUs cost about the same as a triple pane IGU (using a suspended film sandwiched by glass panes) via their automated manufacturing process.
- Four layer glazing using two suspended films sandwiched with glass panes is slightly more expensive than a triple glazed window via the same automated manufacturing process.
- Five layer glazing systems that provide quad-cavities for achieving U-0.05 (R-20) requires manual labor for installation of the third suspended film. This additional step substantially increases costs for production of ultra-high performance suspended film windows.

State-of-the-art Large ICF Block Technology

- In conjunction with strategic design, relatively large ICF block technology that requires no assembly on site can substantially increase productivity.
- In addition, four way reversible blocks with preassembled “T” and “corner” blocks can minimize cutting and waste while allowing for achieving between 150-200 sqft/man hour for trained ICF crews.
- This development of a hybrid panel-block ICF technology allows for competing with the rapidly developing ICF panel technology which currently allows for producing 150 sqft/man hour.

Helix MicroRebar

- Utilizing self-consolidating concrete comprised of about 50% Portland Cement and 50% fly ash with waterproofing additives including rust and corrosion resistant zinc coated Helix MicroRebar can substantially reduce the need for using conventional rebar and vibration technologies.
- This reduction in labor substantially reduces production costs while producing a high performance concrete that is superior to using only Portland Cement.
- Strategic design and innovative engineering allows for minimizing use of conventional rebar for window and garage door openings, suspended floors and vaulted ceilings.

Specialized ICF Crews

- In conjunction with using state-of-the-art materials and equipment including innovative bracing and shoring technologies, experienced ICF crews trained in electrical, plumbing and HVAC installation can reduce labor costs by up to 50% in comparison with conventional stick-frame construction.
- Drilling through wood and pulling cables, cutting and installation of conventional plumbing and conventional HVAC vents and plenums, are unnecessary via state-of-the-art ICF construction.
- Conduit can be installed at the same time as low and high voltage wiring for hybrid AC-DC microgrid designs for residential and small commercial applications. However, using strategic CAT-6 Ethernet cabling, PoE and USB PD technologies that provide up to 10GBASE service; and RG6 coaxial cabling, installation of conduit may not be necessary.

Hybrid Copper & PEX Plumbing

- Time saving PEX tubing and fittings can be used for entire residential applications with the exception of the water meter.
- Both labor and material costs are reduced.
- Provides flexibility and versatility by combining copper and PEX tubing and fittings.

Viega ProPress System

- The ProPress System is the fastest, most reliable, flameless way to press copper tubing.
  - Much faster than soldering (reduce labor by 75%).
  - Safer–no flame.
  - Cleaner–no solder, flux.
  - Convenient–one tool, one source of fittings.
  - Over 25 years of proven performance worldwide.
  - Highest quality.
  - Patented Smart Connect® feature.
  - Wide selection of sizes, types.
  - Meets/exceeds industry standards.
  - Guaranteed reliability.

Centralized Parallel Water Distribution System

- A Viega parallel system provides the lowest pressure and temperature fluctuations in a plumbing system. Since each tubing line is dedicated to an individual fixture, interference between fixtures is eliminated. Additionally, specific fixtures can be supplied by smaller diameter tubing depending on the actual amount of water needed.
- For this type of installation, Viega offers the revolutionary MANABLOC parallel water distribution system, incorporating ViegaPEX tubing and Viega PureFlow PEX Press or PEX Crimp fittings. The Viega MANABLOC system provides a central location to control all plumbing lines and helps homeowners save energy costs and reduce water waste.

Viega MANABLOC parallel water distribution manifold

- Incorporates a system of PEX distribution lines dedicated to individual plumbing fixtures. Because dedicated tubing lines are plumbed specifically to each individual faucet, wait time for hot water is significantly decreased.
- Viega MANABLOCs arrive fully assembled and factory tested. They include individual quarter-turn port shutoff valves, which allow the end user complete control over the entire plumbing system from one central location. Fewer behind-the-wall fittings make it easy to install and less likely to leak. Flexible ViegaPEX tubing in 3/8" and 1/2" ensures optimal efficiency required to supply fixtures.

Energy & Water Conservation

- The choice to install 3/8" PEX tubing for low-demand fixtures instead of 1/2" will determine how much water an end user can save with a Viega MANABLOC system. In a length of 50 feet of PEX tubing, 3/8" PEX stores only .32 gallons of water (as opposed to 1/2" PEX tubing's .46 gallons). Storing less volume of water means less time is required to purge the line and deliver hot water twice as fast in comparison with a 1/2" PEX line.
- Viega MANABLOC is a complete plumbing system that is easy to install and provides fast hot water delivery by decreasing energy costs and reducing water waste.

Viega MANABLOC system

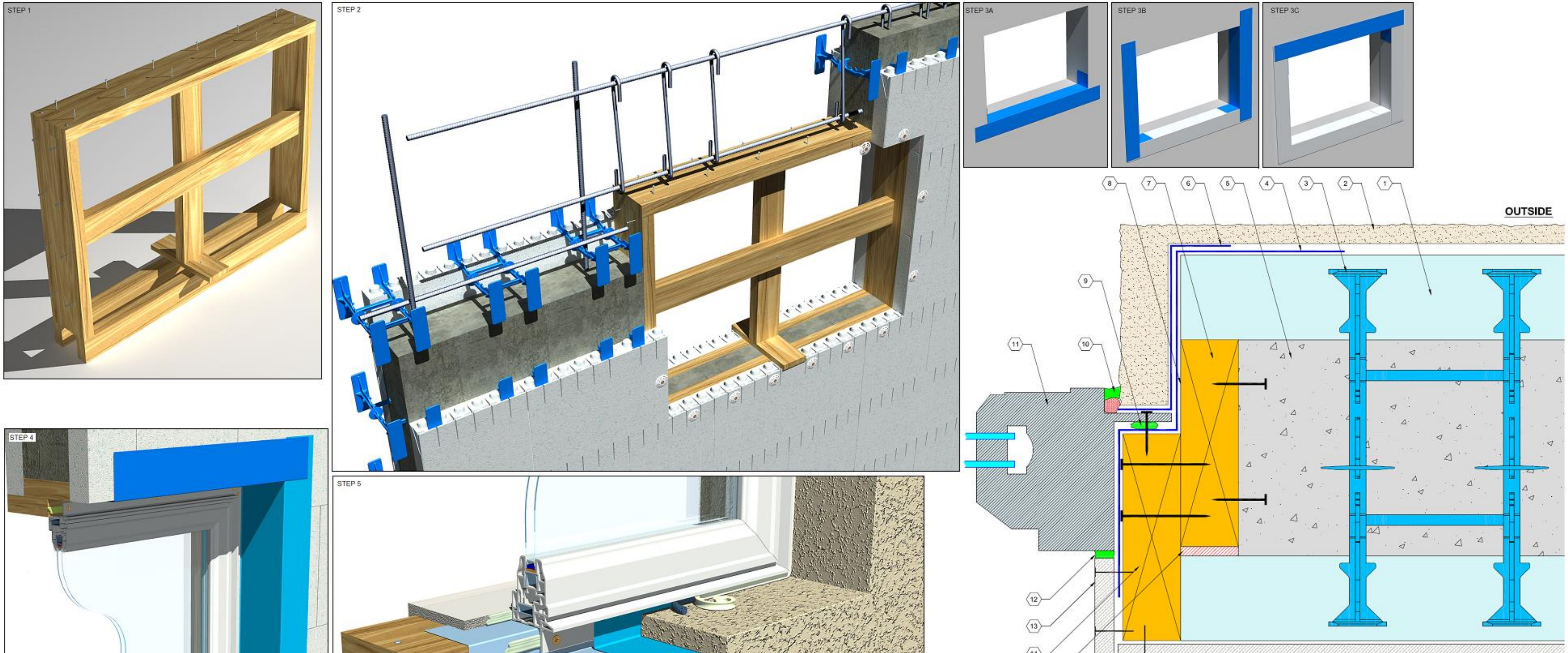
Passive Solar Energy

- A passive solar home requires five elements to take full advantage of solar energy:
  - orientation of the structure (and strategic design and placement of specific high and low gain glazing systems)
  - apertures (windows with high SHGC) to let in the sun’s warming rays
  - a means of preventing too much solar gain in the summer (eaves)
  - an absorber surface that minimizes reflection
  - thermal mass to store the heat until it’s needed (ICF construction of floors, walls, and ceiling)
  - a distribution system to move the heat to where it’s required

Viega MANABLOC Features & Benefits

- Easy to install on each floor for residential applications
- Reduces wasted water
- Increased energy savings
- Delivers hot water fast
- Greater temperature and pressure balance during multiple fixture use
- Complete control of the plumbing system from a central location
- 1-1/4" internal reservoirs help maintain equal pressure during operation
- PLS plastic (polysulfone) resist aggressive water and corrosion
- 10 year limited warranty

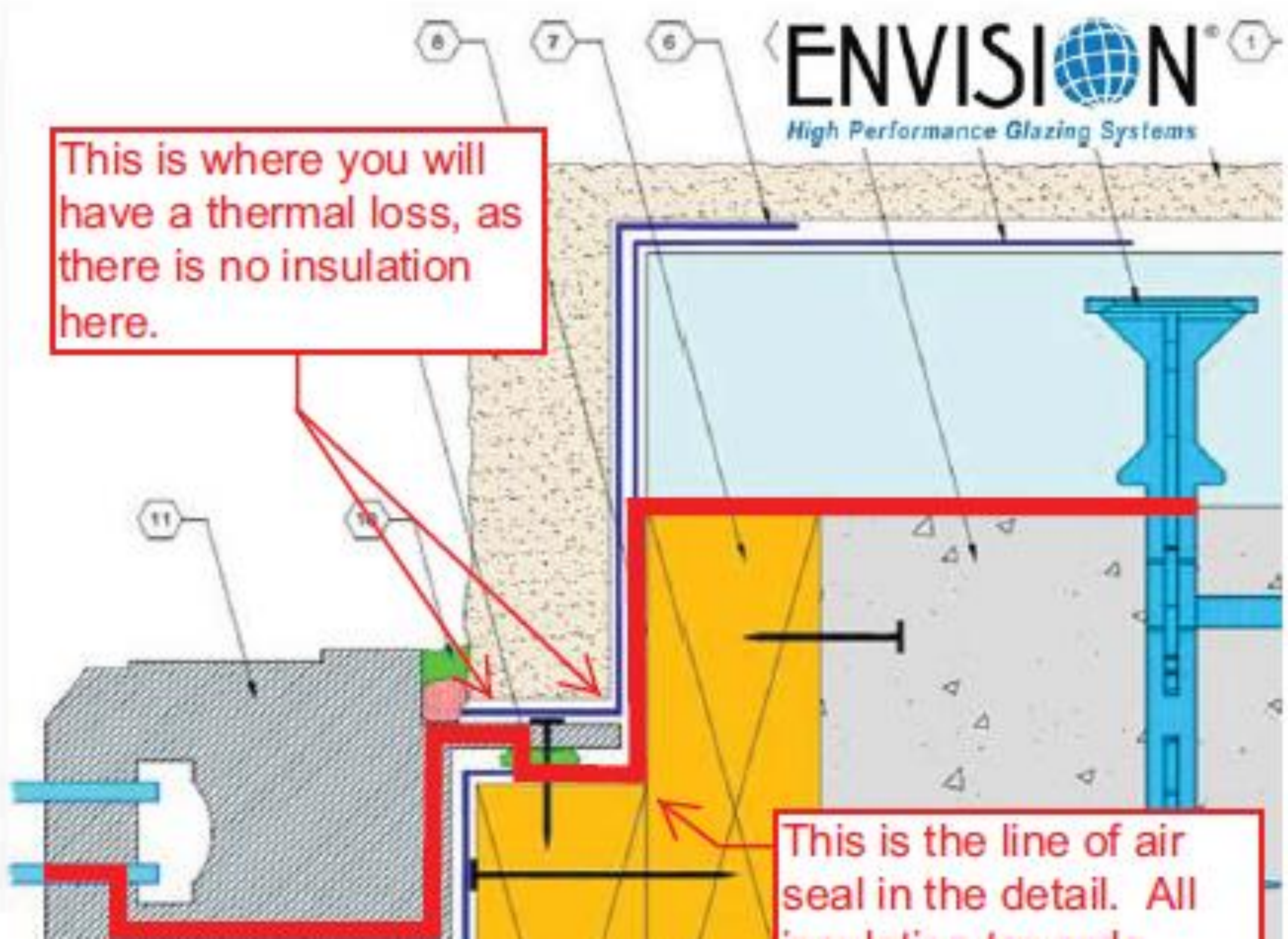
Quad-Lock Internal Window Buck



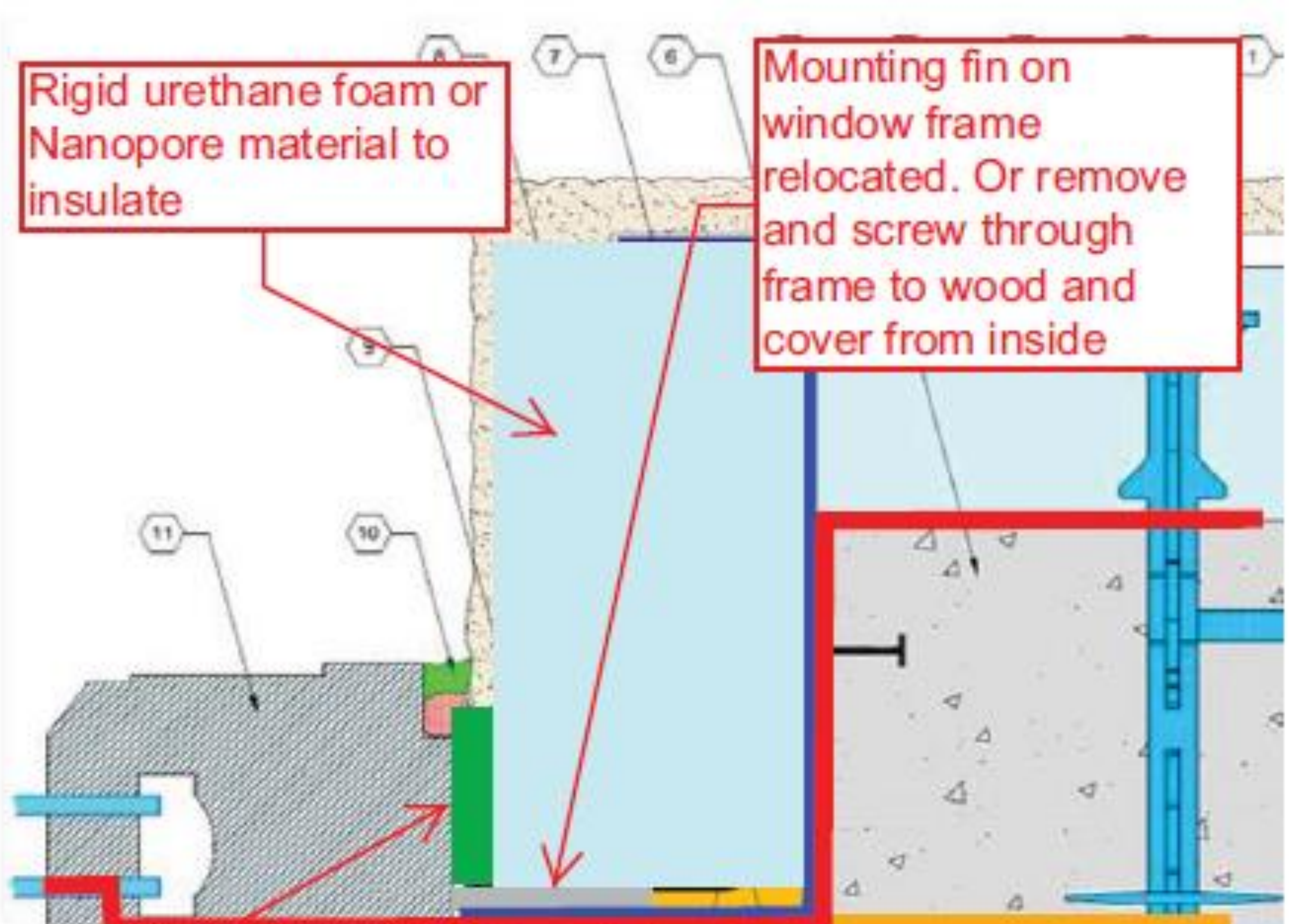
Improved Rigid Urethane Foam Installation for ICF Windows

- A similar though smaller wood block with more foam system (that was anchored to the concrete core) could be used to attach to the window. The slot in the bottom section of the internal buck is used to insure that a good concrete fill is achieved during pouring.
- In addition to the window buck, each of the steps for installation are listed (which would be similar for the R-43 ICF configuration). However, we will use 3” rigid urethane foam cut to size to insulate the core concrete before the window installation in order to eliminate the thermal break created by the pressure treated wood blocking.

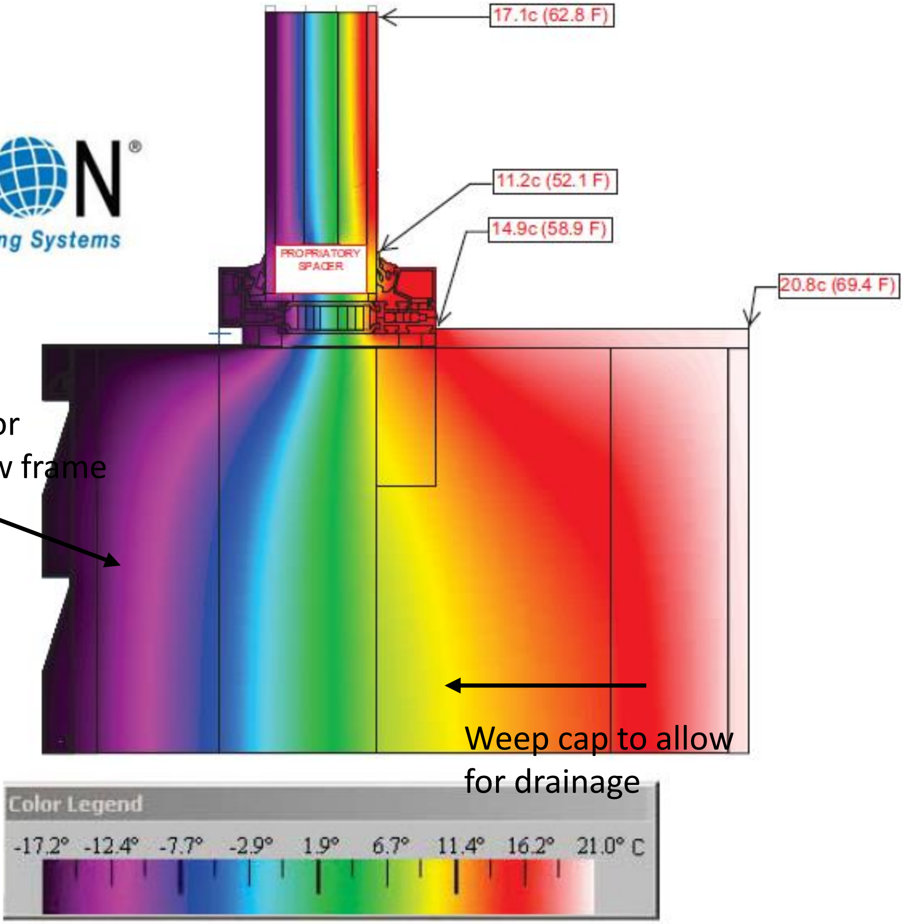
Areas of Improvement For Quad-Lock Window Installation



Improvements Made For Quad-Lock Window Installation



LBNL Therm 7 Infrared Image of ICF Foam Installation



Marvin Windows
Automated Exterior Shade

Available in Slats or Louvers

Exterior Shade Features & Benefits

- Marvin's exterior shading solution includes features and benefits such as:
  - Fully integrated into window – not an add-on
  - Available with Marvin exterior clad casing selections
  - Easy, fully programmable operation.
  - Offers superior control of solar heat gain
  - Shading system is offered in 19 colors to match all standard Marvin clad colors. Slats or louvers are finished in durable Kynar® finish.
  - Shades can easily be replaced by homeowners with exterior access
  - Made in USA – faster delivery than European products
  - Increased occupant comfort through solar heat gain control and additional insulating properties
  - Low-voltage, remarkably quiet integrated motor
  - Self-correcting tracks ensure shades are always in alignment
  - Minimum jamb depths of 6 3/16" for most products
  - An industry-first thermal performance certification pending from PassivHaus Institute and Passive House Institute U.S.

Hammer & Hand Doors

- Passive wood entry doors made in the US lead the industry in energy efficiency.
- Provide an R_{pi}-14 via a 3.5” fir wood and EPS foam insulated door.
- Includes a 5 point locking system and comes with a custom door jam to insure air-tight seal and provide added security.

Flush View of Passive Wood Door

Hammer & Hand Entry Door Production

Quality Entry Door Design & Production

- Vacuum clamping bag used in lamination of Passive House door
- Door jamb of custom Passive House door features in-kerf weatherstripping
- Five point interlocking hardware
- The use of polyiso insulation materials could boost thermal insulation performance to as high as R-12 for 3” wood doors.
- Making these custom doors is labor intensive and hence the cost for a wood polyiso door is $4,000 for entry level doors, and as high as $5,000 for addition of asthetic insets. Mass production could potentially lower costs.

Insulated Exterior Doors & VIP Technology

- Development of porous solids using nanotechnology provide an opportunity to vastly increase the thermal resistance of exterior doors.
- For a 3” wood door, thermal insulation can be increased to as high as R-18 using a state-of-the-art vacuum insulated panel (VIP) material.
- This material ads $700 in material costs to exterior doors.
- Though the R-value of the VIP technology can range as high as R-40/inch, the thermal bridging of the custom made door is what reduces the total R-value of the door to R-18.
- Fiberglass, which has five times the insulation value of wood, can increase the R-value to about R-40 with polyiso foam and R-80 using VIP material.

Advantages of Fiberglass Entry Doors

- Less expensive (less labor intensive) than wood
- Lowest maintenance
- Resists denting and scratching
- Offers wood grain and smooth finish look
- Won’t rot, deteriorate or rust
- Energy efficient (five fold greater than wood)
- Can be painted or stained
- Won’t warp, bow or twist
- Five times the insulation value of wood
- Secure

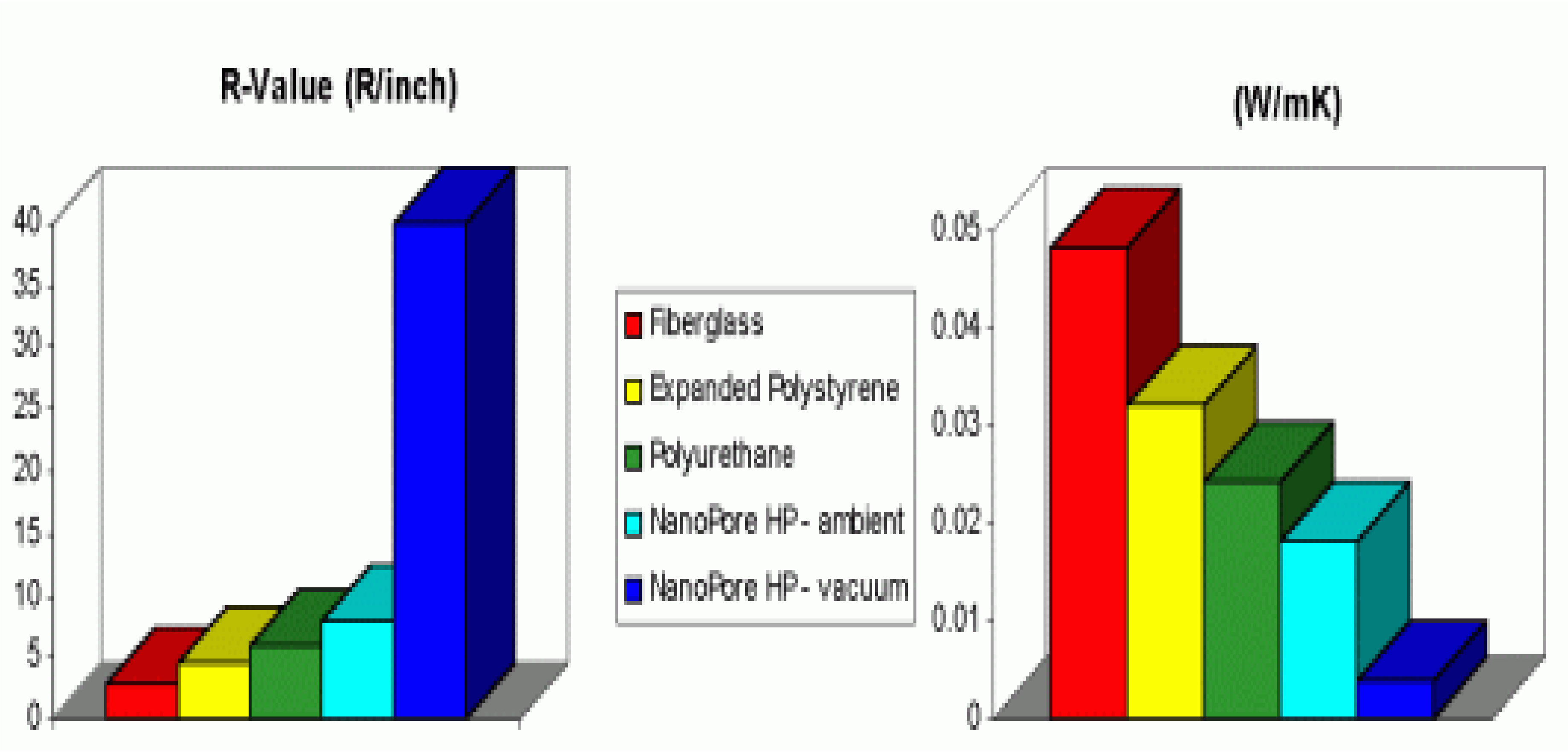
VIP (R-40/inch) Insulation

- **NanoPore™** thermal insulation is a porous solid that is prepared by one of several processes which yield both low density and small pores.
- Its chemical composition is silica, titania and/or carbon in a 3-D, highly branched network of primary particles (2-20 nm) which aggregate into larger (nm to mm) particles.
- The material has pore sizes ranging from 10-100 nm. It is this nano-scale porosity that gives NanoPore™ its excellent thermal performance.

Vacuum Insulation Panel

- Because of its unique pore structure, NanoPore™ Thermal Insulation can provide thermal performance unequalled by conventional insulation materials.
- In the form of a vacuum insulation panel (VIP), NanoPore™ Thermal Insulation can have thermal resistance values as high as R40/inch - 7-8x greater than conventional foam insulation materials.
- A comparison of the thermal performance of NanoPore™ Thermal Insulation versus conventional insulation materials is listed below.

R-40 VIP Insulation



The Knudsen Effect

- Due to the unique nano-structure of VIP products, its conductivity can actually be lower than air at the same pressure.
- Its superior insulation characteristics are due to the unique shape and small size of its large number of pores.
- Gas molecules within the matrix experience what is known as the Knudsen effect, which virtually eliminates exchange of energy in the gas, effectively eliminating convection and lowering overall thermal conductivity.

Solid Phase Conduction

- Solid phase conduction is low due to the materials low density and high surface area, and NanoPore™'s proprietary blend of infra-red opacifiers greatly reduce radiant heat transfer.
- NanoPore™ Insulation may be used over a wide temperature range from below cryogenic (<-196 °C) to high temperatures (>800 °C).

NanoPore™ Thermal Insulation Products

- The standard thermal insulation product is NanoPore™ HP-150.
- It can be used at temperatures up to 300°C.
- For use with higher temperatures NanoPore produces a special high temperature insulation, NanoPore™ HT-170 for use up to 800°C and above in some cases.
- For applications with highly specific performance requirements, custom grades of NanoPore™ Thermal Insulation can be provided to meet a project's special needs.

Semi-rigid Insulation Boards

- NanoPore™ thermal insulation begins as a proprietary blend of nanoporous powders which are pressed into semi-rigid boards.
- The boards are then cut to size and shrink-wrapped for ease of handling.
- For some applications these boards are used directly, but in most cases they are processed into vacuum insulation panels, either by NanoPore or by the end user.
- End users may purchase these boards as VIP inserts.

Vacuum Insulation Panel

- To make a VIP, the inserts are encased in a metalized plastic barrier film and then sealed under vacuum.
- Various barrier materials may be employed to provide the desired performance depending upon the temperature, size, and desired lifetime.
- The completed product is a vacuum insulation panel (VIP).

Temperature Range

- A standard VIP can operate in a temperature range from below -330°F (<-200°C) to 250°F (120°C), the maximum continuous working temperature of the barrier film.
- For higher temperature applications, custom vacuum enclosures, made from metal or another impermeable skin, may be used to house the core material.

Thermal Break Insulation Material

- Vacuum insulation panels (VIPs) may be ideal for providing state-of-the-art thermal breaks for both exterior doors and hybrid window frames.
- Depending on cost, polyiso rigid foam boards or VIPs could also be used to install high performance windows.

Energy Efficient Concrete Tile Roofing

- Locally produced concrete tile has become cost competitive with asphalt shingles while providing superior durability, performance, fire resistance, and curb appeal.
- A variety of colors and artisan/architectural styles are available to choose from depending on climate and geographical region with specific tile produced for harsh freeze-thaw environments.
- In most cases, when properly installed, concrete tiles can last indefinitely without requiring replacing.
- Raised battens provide the ability for air to circulate which virtually eliminates thermal transfer, thus substantially enhancing energy efficiency.

Bartile Concrete Roof Tiles

- **Durable:** 75 year Warranty, Exceeds Class A Fire Rating and Class 4 Hail Rating, Walkable, Made for Harsh Climates
- **Beautifully Custom:** Over 20 Styles and Options in over 700 Colors we can create any look you desire
- **Enviromentally Friendly:** Made of Recycled Material, Long Life Span, Made from Local Materials
- **Saves Money:** Insulates better to save on utility costs, One of the Lowest Lifetime Roofing Products
- Bartile provides standard for **custom colors and styles**.

Factory Blend Sierra Mission Concrete Tile

Appealing Architecture of ICF Structures

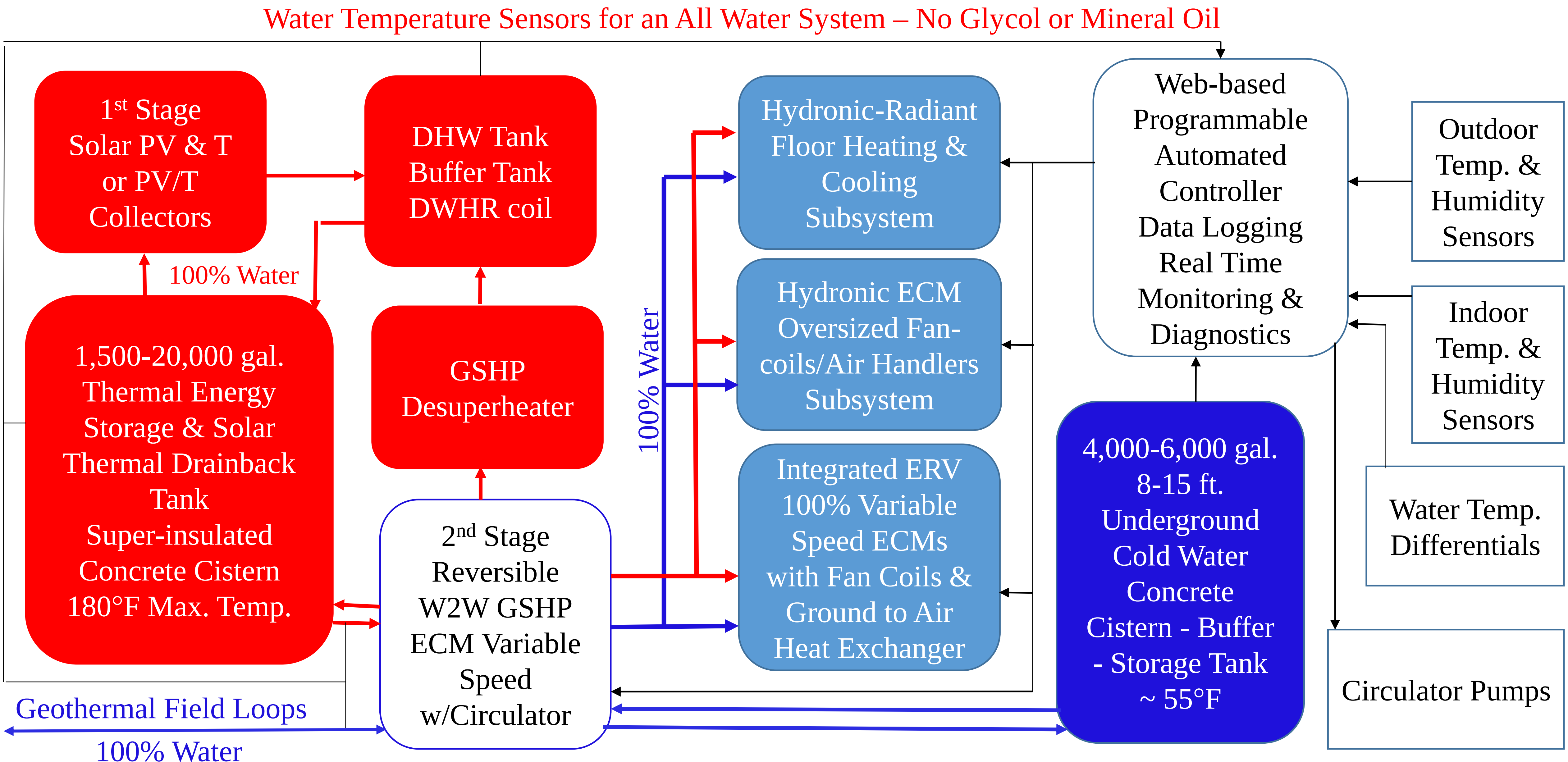
Integrated HVAC System

- Solar thermal collectors, PV collectors, and energy storage systems combined with high thermal mass construction, radiant heating and cooling, and an energy or heat recovery ventilator with ground to air heat exchanger can meet 100% of the DHW and space heating needs of a structure on a sunny winter day.
- For inclement weather, integration of a state-of-the-art 100% variable water to water ground source heat pump (COP 7.0) and desuperheater powered primarily by the solar PV system can supplement the solar thermal collectors, provide hydronic cooling, and regulate humidity in conjunction with 2nd stage forced air provided by oversized fan-coils inserted into the ERV/HRV.

Minimizing ΔT (Temperature Differential)

- The less energy required by an HVAC system to meet DHW and space heating and cooling requirements, the more efficient that system will be.
- In conjunction with high-thermal mass design for radiant floor heating and cooling, up to 40% of the energy of high-mass structures can be conserved.
- This allows for minimizing the ΔT of the HVAC system for that structure. In other words, the entering water temperature and the leaving water temperature of the radiant system can be as little as 10-20°F, possibly less than 10°F for strategic passive house designs.

Integrated HVAC System Flow Chart



Solar PV vs. Solar Thermal

- Though solar thermal systems can achieve energy conversion efficiencies of 80-90%, they are substantially more expensive to install and require considerably more maintenance in comparison with solar PV systems.
- Solar PV panels have decreased in price by 80% over the last five years and are expected to decrease by another 30% by 2016.
- Solar PV are also less costly to install and require much less maintenance in comparison with solar thermal systems.
- Recently, government grant programs have focused almost entirely on improving efficiency and reducing soft costs of implementing solar PV technology.

Comparing Solar Thermal & PV Systems

- Compared to a PV system, a solar thermal system has several disadvantages:
- Unlike a PV system, most solar thermal systems have moving parts (pumps and solenoid valves).
- In freezing climates, solar thermal systems are sometimes subject to freeze damage.
- Solar thermal systems require regular maintenance, including antifreeze replacement.
- Unlike owners of a grid-connected PV system, who can be credited for their excess electricity production during the summer, owners of a solar thermal system can't sell the excess summer production of their hot water systems.

Comparing Solar Thermal & PV Systems cont.

- While a pole-mounted PV array can include a tracking mechanism to follow the sun's path across the sky, it's virtually impossible to install solar thermal collectors on a tracker.
- On average, PV systems probably last longer than solar thermal systems. This is due largely to lower maintenance requirements.
- There are far more stories of troublesome solar thermal systems than there are stories of troublesome PV systems. Solar thermal systems sometimes develop air bubbles that interfere with the circulation of fluid, suffer from leaking pipes, or experience problems from summertime overheating. PV systems, which suffer none of these headaches, look attractive in comparison.

Solar PV & Solar Thermal

- Solar PV systems can range from 20-45% conversion efficiency.
- The majority of solar PV technologies range from 15-22% conversion efficiency.
- This reveals that 55-85% of the energy produced by solar PV panels is thermal energy.
- As the temperature rises, solar PV conversion efficiency drops due to resistance which results in production of thermal energy.
- Hence, there is potential to simultaneously maintain solar PV conversion efficiency while capturing the associated thermal energy.

State-of-the-Art W2W GSHP Technology

- With water to water (W2W) ground source heat pump (GSHP) technology advances using electrically commutated motors (ECM) and 100% variable operation, coefficients of performance (COP) can now range as high as 7.0 for properly designed systems powered primarily by solar PV and associated net-metering systems.
- By strategically installing geoexchanger field loops around the footings of a basement for a super-insulated passive house (which reduces peak heating and cooling loads by over 95% for ICF structures), costs of GSHP installations can be reduced by up to 50%.

Solar PV & DC Powered GSHP Systems

- One of the advantages of powering GSHP systems with solar power is eliminating the 30% power losses for converting DC to AC and then back to DC.
- During the day when the PV system is producing DC power, this power source can be utilized directly by the GSHP and other DC powered devices throughout a structure such as a passive house.

Strategic Battery Storage Design

- When a DC battery storage system is included with a solar PV system, optimal energy efficiency can be attained.
- Since large battery systems are expensive, especially for lithium ion technology similar to that used in electrical vehicles, battery systems can be strategically designed to fill the gap for provision of DC power during evenings when the sun is not shining, then be re-charged during the day.

Solar Photovoltaic (PV) Panels

- These direct current (DC) electricity-producing panels have been available for several years and with the introduction of Feed in Tariffs are a very cost effective way of producing electricity and generating revenue.
- One little-mentioned drawback with PV is that as the surface temperature of the panel rises, the output drops.

Solar Thermal Collectors

- Traditional solar thermal installations collect the sun's heat and convert this into hot water, typically meeting a property's summer hot water requirements.
- A major drawback is that in times of little or no sun there is little or no hot water.

Heat Pumps

- Heat pump technology has been available for many years and installations of both ground-source and air-source systems are meeting heating demands all over the world.
- However, whilst these devices are potential greener than burning fossil fuels, they do still use large amounts of electricity.

The Hybrid Solar Solution

- The Hybrid Solar Solution combines all three of the above technologies in such a way that the aggregate system outputs are far greater than those produced by the components individually.

The Hybrid Solar Solution cont.

- PV, as already mentioned, has a linear drop-off in efficiency as the surface temperature of the panel rises. Given that PV panels are typically black and mounted in such a way as to get maximum exposure to the sun, this rise in panel temperature is inevitable.
- PV panels typically lose efficiency of up to 0.5% per degree rise in panel temperature.

Photovoltaic Thermal (PV-T) Collector

- However the Hybrid Solar Solution combines both the PV and Thermal elements onto a single panel - a photovoltaic thermal (or PV-T) collector.
- This has two main advantages; firstly, by drawing heat away from the panel the electrical output is maintained at a higher level for a longer period, and secondly, with the PV and Thermal elements combined on a single panel less roof area is required, allowing for greater outputs on equivalent roof space.

Integrating Solar Thermal & GSHP

- The output of solar thermal is dependent on sunlight so for half the day and most of the winter a solar thermal collector operates very inefficiently and the heat collected is often at a much lower temperature than that required for use in a house.
- With the integration of the heat pump, the output of the thermal collector is no longer directly related to the intensity of the sun and therefore a constant output temperature can be achieved irrespective of solar input.

Advantages of Integration

- Heat can be collected from the panel at night as the surface of the panel will act as a thermal absorber rather than solar collector
- The temperature of water in the house can be set and achieved irrespective of levels of irradiance (sunshine).

Increasing COP of Water to Water GSHP

- COP is a simple calculation of electrical energy input versus thermal energy output. However, the COP of a heat pump changes across the seasons as the result of the seasonal drop in source temperature. In other words, as the input temperature of the source reduces (colder ambient ground or air conditions), and the difference between latent heat input and upgraded heat output rises, so the COP falls.
- Air-source heat pumps are most susceptible to this; when the ambient temperature drops to below freezing the COP will drop off dramatically. Ground source heat pumps are more stable and do not have such a wide spread of COP due to the relative constancy of the energy source.

Hybrid Solar Thermal & GSHP Solution

- The Hybrid Solar Solution maximizes the advantages of air-source (namely low cost) without the downside of extremely inefficient performance in freezing conditions.
- The Hybrid Solar Solution collects its heat from the PV-T panels, so even in winter, under direct sunlight, the panels will be providing an input temperature far greater than the ambient air temperature, and generally well above ground-source, particularly at the end of a harsh heating season when the ground may well have frozen.
- This means that the operating COP of the Hybrid Solution surpasses those of other domestic heat pump technologies.

Photovoltaic Thermal Hybrid Solar Collectors

- Sometimes known as **hybrid PV/T systems** or **PVT**, are systems that convert solar radiation into thermal and electrical energy. These systems combine a photovoltaic cell, which converts electromagnetic radiation (photons) into electricity, with a solar thermal collector, which captures the remaining energy and removes waste heat from the PV module.
- The capture of both electricity and heat allow these devices to have higher exergy and thus be more overall energy efficient than solar photovoltaic (PV) or solar thermal alone. A significant amount of research has gone into developing PVT technology since the 1970s.

Hybrid PVT Systems

- Photovoltaic cells suffer from a drop in efficiency with the rise in temperature due to increased resistance. Such systems can be engineered to carry heat away from the PV cells thereby cooling the cells and thus improving their efficiency by lowering resistance. Although this is an effective method, it causes the thermal component to under-perform compared to a solar thermal collector. Recent research showed that photovoltaic materials with low temperature coefficients such as amorphous silicon (a-Si:H) PV allow the PVT to be operated at high temperatures, creating a more symbiotic PVT system. This advantage can be tuned by controlling the dispatch strategy of thermal annealing cycles.

PV/T Liquid Collector

- The basic water-cooled design uses conductive-metal piping or plates attached to the back of a PV module. The fluid flow arrangement through the cooling element will determine which systems the panels are most suited to.
- In a standard fluid based system, a working fluid, typically water, glycol or mineral oil is then piped through these pipes or plate chillers. The heat from the PV cells are conducted through the metal and absorbed by the working fluid (presuming that the working fluid is cooler than the operating temperature of the cells).

Open & Closed PV/T Liquid Systems

- In closed-loop systems this heat is either exhausted (to cool it), or transferred at a heat exchanger, where it flows to its application.
- In open-loop systems, this heat is used, or exhausted before the fluid returns to the PV cells. It is also possible to disperse nanoparticles in the liquid to create a liquid filter for PV/T applications. The basic advantage of this type of split configuration is that the thermal collector and the photovoltaic collector can operate at different temperatures.

Consumer Electronics & Small Appliances

- According to the Energy Information Agency (EIA), the fastest growing portion of residential electricity use is consumer electronics and small appliances. In 1993, the EIA did not even bother to measure the consumption in either category; eight years later it counted over a dozen types of devices that fit in this category. By 2013, when a group of IEEE members audited their houses to get a snapshot of what they had, the list of categories expanded to over 50 small appliances and consumer electronics devices.
- These devices primarily run on DC power. Even with improvements in power supplies, many of these devices have a conversion efficiency of no better than 80% and some low-end devices have efficiencies as low as 65% in converting power.
- Such devices now account for between 15 and 30 percent of a residence’s consumption, depending on demographics, country and weather zone.

Conversion & Transmission Losses

- In terms of electricity used, in 2012 the average U.S. home consumed 11,252 Kilowatt-hours (kWh). Assuming the average home used 20% of electricity for these devices, that translates into 2,250 kWh consumed by each residence. With an average efficiency of power conversion of 75%, that means 562 kWh were lost in power conversion in an average home.
- If this were the only loss from power conversion, it might be ignored, but this is not the case. On the production side of the equation, residential photovoltaic systems are coming into wider use, producing DC power that also involves significant losses. The smallest PV system typically installed has a capacity of about 1 kilowatt (KW) and produces 5250 kWh annually.

Over 46% Solar DC-AC-DC Energy Loss via Net-Metering Systems

- According to the National Renewable Energy Lab's (NREL) PVWatts tool, the losses associated with converting DC to AC in a typical system come to 23%, or 241 kWh. The average size installed is 5 KW, so the annual conversion loss amounts to 1,200 kWh for the average system.
- Then there are electric vehicles, a third major DC element. According to GM, the Chevy Volt needs to have 10.4 kWh fed into the battery for a full charge because of losses and battery conditioning, doing that actually requires 12.9 kWh of electricity. Assuming the Volt is driven the 35-miles-a-day national average, which is roughly the number of miles the car gets per charge, it will consume 4,700 kWh of electricity per year, of which 912 kWh is lost in conversion and charging the batteries.

Over 70% Reduction in Energy Consumption

- So, if current trends continue, more renewables, electric vehicles and consumer electronics will be installed, leading to growing conversion losses. Today, a home with photovoltaic and electric vehicles will see conversion losses of 2,674 kWh annually on a consumption of 15,952 kWh, or 16%. This means more electricity is lost within the home than in delivering that home’s power across the distribution and transmission grids.
- For zero net energy homes that strategically implement hybrid AC-DC distribution for solar PV homes, total energy consumption by an average household can be reduced by well over 70% via passive house design, hybrid AC-DC microgrid, DC appliances, DC powered LED lighting, alternative energy HVAC technology including radiant floor heating and cooling, installation of state-of-the-art battery storage, and a state-of-the-art home energy management system.

Direct DC Motivating Factors

- Interest in ‘direct-DC’ power distribution is motivated by a combination of factors:
  - the very rapid increase in residential and commercial photovoltaic (PV) power systems in the United States;
  - the rapid expansion in the current and expected future use of energy efficient consumer electronics products (comprised of semi-conductors) that utilize DC power;
  - the demonstrated energy savings of direct-DC in commercial data centers;
  - and the current emergence of direct-DC power standards and products designed for grid-connected residential and commercial products.

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems**)**

Mature Off-Grid Markets for DC Appliances

- DC appliances have served niche markets for decades, offering proof of their capacity to deliver energy services for all major electricity end-uses.
- Markets for stationary applications include off-grid residential, telecom, remote scientific monitoring stations, and emergency shelters. The products are designed to be energy efficient, because of the high cost of supplying electricity to these generally remote locations.
- Mobile applications include rail, marine, and road transportation (trucks, recreational vehicles, and automobiles) and are designed to be rugged (vibration-resistant) as well as efficient. These DC appliances tend to be higher priced (per unit of service) and smaller (in the case of large appliances) than their mainstream counterparts, but their fundamental designs are applicable to mainstream use, and prices would come down with mass production.

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems)

DC-Compatible Electricity End-Uses

- Large energy savings are possible from switching from AC appliances to DC-compatible appliances, even if they are running on AC. All of the 32 electricity end-uses investigated in this report were found to be DC-compatible; indeed DC-based design increases the efficiency of all major residential and small commercial end-uses, including cooling, lighting, space and water heating, clothes washing, and dishwashing. DC is essential for all electronics.
- Key DC-based technologies include electronic lighting (fluorescent and solid state) and DC motors (driving fans, pumps, compressors and other devices, in particular in variable-speed operation where appropriate).

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems**)**

33% Increase in Energy Conservation

- An increasing fraction of the residential and commercial load is DC-internal, increasing the logic of DC power use in buildings. The LBNL estimates that 33% of residential electricity use could be saved by converting all appliances to high-efficiency, DC-internal technology running on AC.
- Direct-DC power systems could offer additional savings by eliminating the AC-to-DC conversions losses, which constitute on average 14% of the AC load. Note however that, if grid backup power is used to supply DC loads, AC-to-DC conversion losses will reduce the net savings to less than 14%. Savings should be higher for the commercial sector because of the greater coincidence with insolation and load, particularly for space cooling.

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems**)**

Dominant AC Electricity End-uses in the US

Table 1. Dominant AC electricity end-uses in the U.S. residential and commercial sectors showing energy use (quads) in 2010 and electricity usage rankings.

End Use	Residential (quads)	Ranking	% of sectoral total	Commercial (quads)	Ranking	% of sectoral total
Cooling	0.79	1	16%	0.5	3	11%
Lighting	0.72	2	15%	1.12	1	24%
Refrigeration	0.45	3	9%	0.23	5	5%
Sub-total	1.96		40%	1.85		39%
US Total	4.95			4.73		
Subtotal as percent of total	40%			39%		

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems)

24VDC Occupied Space Standard

- While EVs and PHEVs are creating new DC demand, other products are entering the market to distribute DC power directly to appliances, which in turn is stimulating a new market in DC appliances.
- The EMerge Alliance, an industry alliance promoting the use of direct-DC, is registering products that are designed to meet its new 24VDC Occupied Space Standard. Notable is the Armstrong Ceiling, which integrates the 24VDC bus into the metal framework that traditionally holds the tiles in a commercial drop ceiling. With this product, 24VDC appliances and controls can be easily installed and relocated without the need of an electrician. Nextek Power Systems has produced DC lighting and fans, while Lunera, Focal Point, and Cooper have all produced 24V luminaires, to couple to the EMerge ceiling.

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems)

New PoE & 380VDC Standards

- Power over Ethernet (PoE) is another existing low voltage DC distribution system. PoE standards are evolving to accommodate higher power devices. The Institute of Electrical and Electronics Engineers (IEEE) has revised the PoE standard (IEEE802.3) rapidly upward from 15.4W in 2003, to 25W in 2009 (both at 48VDC).
- The Institute is currently developing a new standard that is expected to extend that limit to 65W at 51-54VDC, offering the opportunity to power an expanding universe of consumer electronics. While the current EMerge system and PoE cannot power large appliances, EMerge is now developing a 380VDC standard to meet large loads in data centers and telecom central offices. Together, the two standards provide a foundation for serving all residential and commercial loads.

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems)

DC Power Standards For Homes & Small Businesses

- In Jan 2014, EMerge launched an initiative to develop DC power standards for homes and small businesses, largely aimed at enabling “hybrid” systems that can simultaneously run DC and AC over typical household wiring.
- “You’re going to be in a hybrid mode most of the time -- some AC and some DC,” EMerge Chairman Brian Patterson said. “When you’re figuring out how they’re all going to fit together, you have to figure out where all these hybrid interfaces are going to be in the network.”

100 W USB Power Capacity

- As for how household electronics will fit into a DC-powered home, EMerge is looking forward to next year's release of a new USB PD (power delivery) standard, which is meant to boost USB's power capacity to 100 watts, ten times what's possible today. That could enable direct DC power for a whole new set of consumer electronics, as long as the standard interfaces are there to power them.
- Reducing the inefficiencies inherent in AC-to-DC conversion is "just the beginning of the story," he said. "It's more about how we manage that power. We want personal electronics to power down when we're not using them, and wake up when we need them -- and that's going to be electronic management."

PoE vs USB Power Delivery

- Extending USB's power capability is also a response to Power over Ethernet, which has more flexible dynamic power negotiation capabilities up to 48 V DC and up to about 1 A, and whose maximum bandwidth is potentially greater than even USB 3.1's 10 Gbit/s.
- The combination of USB 3.0 and a 6 A limit at the most common (5, 12, 24 V DC) voltages would permit support of a wider variety of devices, although powered Ethernet can support them at longer cable distances, however, IBM’s PoweredUSB does not incorporate USB 3.x officially. In general, since the voltage drop at high currents can be significant over even a few meters, higher voltages are desired for larger distances.

USB Power Delivery (USB PD)

- In 2012, the USB-IF released the USB Power Delivery Specification (USB PD) as an optional part of the USB 2.0 and 3.x specifications. It defines features similar to those addressed by PoweredUSB, but without requiring the use of proprietary connectors.
- Instead, the connectors defined in the USB 2.0 and 3.0 standards are continued to be used; higher currents require PD-aware USB-cables, though. USB hosts compliant with this USB specification can be requested by USB devices to provide alternative voltages (12V and 20V) and higher currents — up to 2 A at 5 V (for a power consumption of up to 10 W) and optionally up to 5 A at either 12 V (60 W) or 20 V (100 W).[8]

USB PD & The Internet of Things

- The USB PD technology comes just in time for the "internet of things"—the idea that devices and gadgets can talk intelligently and automatically to each other online.
- That will mean many millions of new bits of equipment, all needing their own power supply and means of communication.
- The new USB standard provides both.
- Next development is to make the USB cable "flippable"—so that the plug fits the socket whichever way it is inserted (for now it works only one way round).

PoE vs. USB PD

- The IEEE 802.3af Power over Ethernet (PoE) standard specifies a more elaborate power negotiation scheme than powered USB. It operates at 48 V DC and can supply more power (up to 12.95 W, PoE+ 25.5 W) over a cable up to 100 meters compared to USB 2.0, which provides 2.5 W with a maximum cable length of 5 meters.
- This has made PoE popular for VoIP telephones, security cameras, wireless access points and other networked devices within buildings. However, USB is cheaper than PoE provided that the distance is short, and power demand is low.

PoE Safety Advantage

- Ethernet standards require electrical isolation between the networked device (computer, phone, etc.) and the network cable up to1500 V AC or 2250 V DC for 60 seconds.
- USB has no such requirement as it was designed for peripherals closely associated with a host computer, and in fact it connects the peripheral and host grounds.
- This gives Ethernet a significant safety advantage over USB with peripherals such as cable and DSL modems connected to external wiring that can assume hazardous voltages under certain fault conditions.

International Support for Direct DC

- While EMerge is clearly the most visible actor influencing the evolution of direct-DC in the United States, there is international interest as well. The two main international actors both have strong industry partners. Japan’s New Energy and Industrial Technology Organization (NEDO) has worked closely with Panasonic in direct-DC research and development. In Korea, Samsung, working with the Seoul National University, appears to be farthest along in residential direct-DC, having completed a residential DC demonstration project in 2009.
- While there is clear interest in international and intra-national cooperation in the development of DC standards for building and vehicle charging, success in this endeavor is essential for the direct-DC market to develop and for potential energy savings to be realized.

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems)

Direct Current (DC) Power Distribution

- Solar panels generate direct current (DC) power, and computers, printers, telephones, lights, and pretty much every other typical office power load uses DC power.
- Overall, shifting power loads to DC can improve building energy efficiency by 25-35%. That is primarily achieved by cutting power conversion losses of 15-20% percent on each transition from DC to AC and back again.
- That's a general figure -- next-generation power electronics systems can cut conversion losses down to the low single digits. But direct DC power cuts that down to zero.

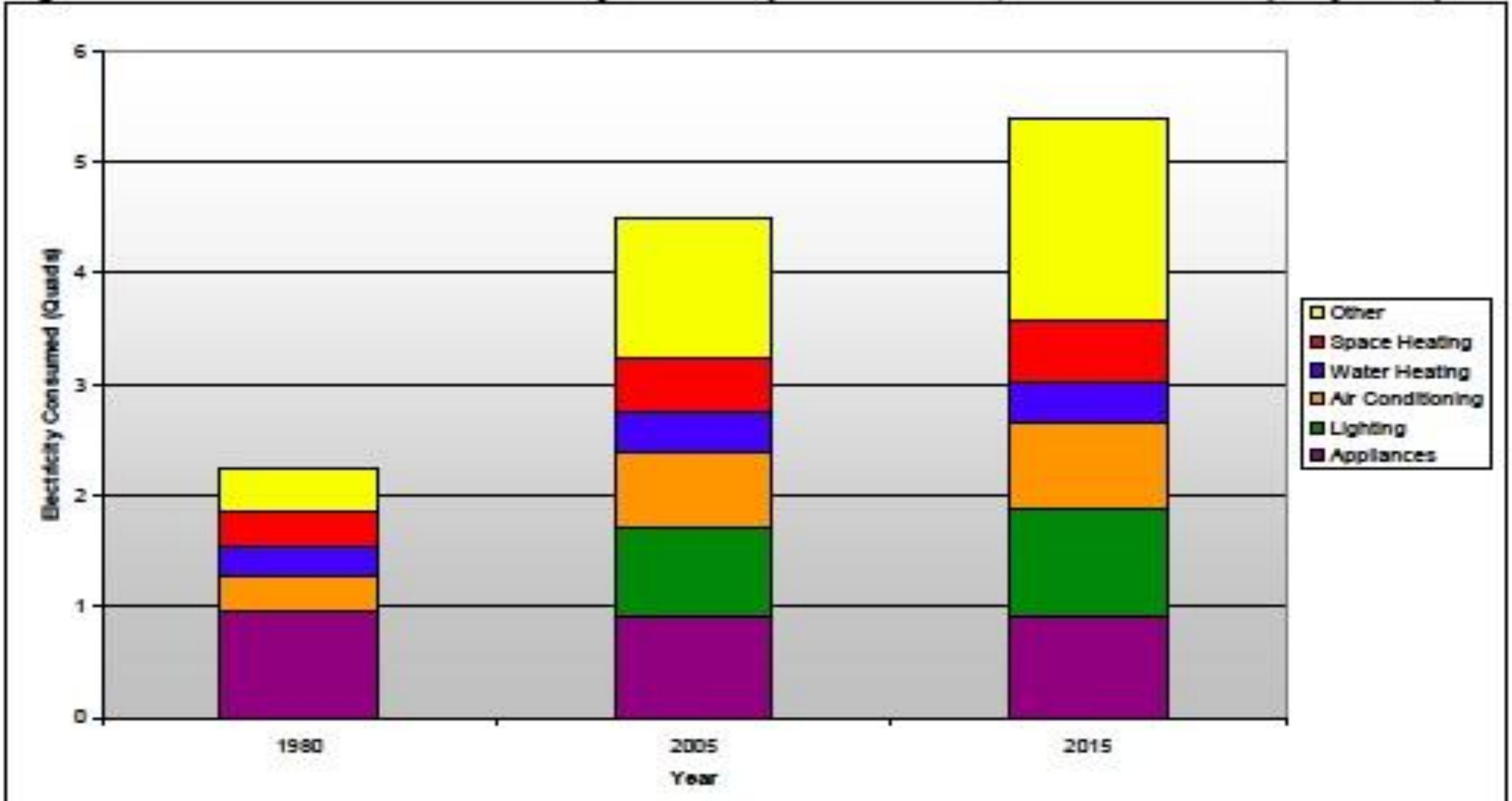
DC & AC Powered Smart Homes

- Home energy management systems, coupled with batteries that store power from the grid, as well as from small-scale solar PV systems can provide DC power that will supply LED lights in buildings, as well as use USB to power an array of consumer electronics.
- The DC “above the waist” loads in the home, are in contrast to “below the waist” appliances, pumps and other systems that will continue to run on grid-supplied, AC power.
- According to energy experts, while household power demand for these below-the-waist devices isn’t growing that fast, “the stuff above the waist keeps going up exponentially, and nobody knows what it’s going to be like in 2020.

Growing Increase in DC Power Demands

- In light of the increases in DC power used in residential structures, utility companies are struggling to provide peak power to homes and businesses where digital devices make up the fastest-growing share of electricity usage.
- The U.S. Energy Information Administration (EIA) has projected that household energy use attributable to miscellaneous devices, much of it consumer electronics, is set to nearly double between 2005 and 2015, while most other classes of loads show little projected growth.

Figure 1. Total Residential Electricity Consumption for 1980, 2005 and 2015 (Projected)



30% Decrease in Energy Consumption

- Using DC power from batteries to power LEDs and digital devices could improve the efficiency of homes by roughly one-third, compared to the losses that come from converting that power from AC to DC.
- Allowing solar PV's DC output to go directly to batteries or the home's DC loads could also improve efficiencies on that side, allowing smaller solar systems than would otherwise be practical.

Additional 20% Decrease in Energy Consumption

- In addition, by putting in a very small solar PV system, with roughly 1 to 2 kilowatt-hours of storage matched to LED and electronics loads, an additional 20% decrease in daytime consumption can be achieved.
- This can allow for reducing the average peak in energy usage by about 50%.
- That’s a significant opportunity in a country where half the peak is driven by domestic power usage.

Development of DC Power Technology

- China's Xiamen University is using DC power to connect rooftop solar panels to lights, HVAC systems, data centers and plug-in vehicle chargers.
- Nextek Power Systems is providing the solar-to-building DC power technology, China-based Canadian Solar provides the solar panels, and Palo Alto, Calif.-based startup People Power will provide the cloud-based software platform to connect it to people in the building.

Development of DC Power Technology cont.

- Lawrence Berkeley National Laboratory will provide “algorithms for the optimal equipment choice and operation of direct-current microgrids.”
- LBNL hosts the U.S.-China Clean Energy Research Center, part of the joint U.S.-Chinese smart grid partnership formed by Energy Secretary Steven Chu in 2009.
- Intel is providing “technical expertise and advice,” and has been working on DC power research at an Intel Labs energy research facility in New Mexico.

DC Power Standards

- Buildings still have to convert DC to different voltages depending on the application.
- The EMerge Alliance, a DC building power consortium of big names in the electronics and buildings fields, has set a 380-volt standard for powering data centers, and a 24-volt standard for its “occupied spaces” category, which includes offices and anywhere else people roam freely.

Cloud-based Software Management Platform

- People Power is a start-up company founded by former Bitfone and Computer Motion CEO Gene Wang.
- They are taking a winding path through various smart-energy plans, from building its own chipsets for in-home networked devices to creating the cloud-based software management platform that runs them in unison.
- It is working with Texas Instruments, Ricoh, Blue Line Innovations and others, though it hasn’t claimed any big deployments yet.

Interactive Building Energy Technology

- In the case of Xiamen, People Power will run the system that lets people interact with building energy use, setting office cubicles to turn off when they're not being used, powering data centers up and down to meet IT demand, and the like.
- The startup wants to embed its operating system in office equipment, lights, power strips and anything else that can connect to the Internet.

Widespread Interest by Technology Leaders

- Data centers have been a major focus for DC building power, with companies like ABB, General Electric and Emerson getting involved.
- Facebook's super-efficient Oregon data center runs on DC power, and using LEDs instead of fluorescent lights also benefits from the fact that LEDs run on direct current.
- As for the solar connection, AMD, HP and others are looking at ways to tap wind and solar power directly to feed servers, though of course, they all need steady backup power to keep humming.

Eliminating AC-DC Power Converters

- While the Xiamen project isn't taking on direct-to-the-desktop DC power, the EMerge Alliance has launched a task force to work on the idea of powering computers, printers and other plug-in office gear without those pesky, wasteful converters on every power cord.
- Of course, that also means switching out all the outlets in the office with a DC equivalent of some kind, which limits its potential as a retrofit technology.

Safe DC Power Distribution

- The Emerge Alliance is developing safe DC power distribution standards aiming to integrate solar power, batteries and LED lighting and home electronics into a single DC-powered system.
- The goal is to reduce inefficiencies related to converting DC to AC and back again, and bring the control capabilities that come from a core DC power technology -- the USB cable -- to better manage household power loads for grid needs.
- In Nov 2013, Emerge launched of a new residential DC power standards initiative to advance the use of DC power in homes and small businesses. The Alliance is the only application standards development group working on advancing the use of DC power in residential and commercial buildings.

DC Power Distribution: Economics & Versatility

- DC power distribution would not only maximize the efficiency and ROI of rooftop solar panels by enabling them to directly power consumer electronics, appliances, LEDs and electric vehicles (EVs) without conversion losses, it could also give homeowners a choice to either store excess DC power or continue selling it back to power companies.

Hybrid use of AC & DC Power

- Like all EMerge Alliance standards, this new residential initiative will include the hybrid use of alternating-current (AC) and DC power by defining interfaces with existing AC power systems at various upstream and downstream levels, with the goal of providing plug-and-play convenience for homes and small businesses, including faster EV charging and direct support of the expanding use of USB, wireless charging and other low-voltage DC power distribution means that simplify the convenient and efficient use of personal electronics and home automation equipment.

Industry Leadership & Collaboration

- As a next step, the Alliance will form a technical committee to identify needs and opportunities for residential DC power standards.
- EMerge Alliance members will collaborate with organizations like IEEE, the world's largest professional association for the advancement of technology, and NextEnergy Center's NextHome, a DC-connected house demonstration project, to determine best practices for implementation.

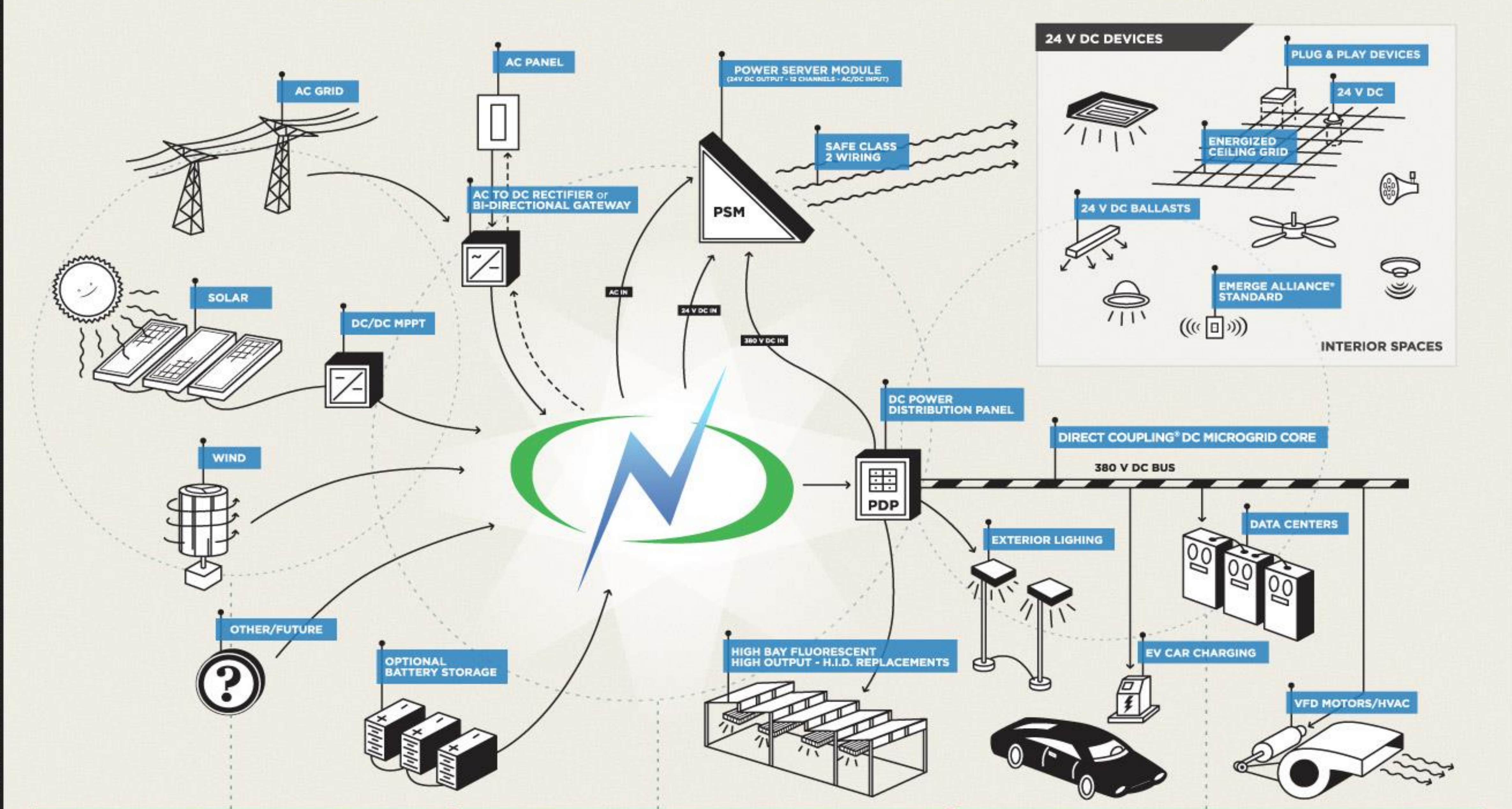
Smart Home DC Power Distribution Lab

- NextHome, a connected smart home with a direct current (DC) power distribution system, operates as a “living lab” within NextEnergy’s testing and validation platforms.
- The DC power distribution system allows companies to test and demonstrate next generation energy technologies in a real world environment without conversion from alternating current (AC) to DC at the point of use.
- This includes, LED lighting, HVAC, appliances, consumer electronics, renewable energy, energy storage, energy management systems, open source communication systems, and electric vehicles.

DC Microgrid Core

- Technology exists which eliminates the need (for buildings with onsite power generation and traditional AC grids) to convert power from DC to AC to distribute it, then back to DC when it is used to power devices such as computers.

HOW DOES A DC MICROGRID WORK?



High Performance MPPT DC-DC Converters

- The embedded MPPT algorithm in these DC-DC converters maximizes the power generated by photovoltaic panels independently of temperature and the amount of solar irradiation.
- The conversion efficiency for HP MPPT DC-DC can range as high as 97%.

Nextek Power Server Module

- Nextek’s Power Server Module converts 120, 208, 240, 277 VAC, or 380 VDC power to 24 VDC through 16 individual Class 2 outputs. The Power Server Module has a wireless remote control and monitoring system.
- The system advantage of the Power Server Module is a safe, low-voltage DC distribution system that supports quick plug-and-play, energy efficient and individually controllable Direct Current (DC) lighting and other loads.
- Nextek’s Power Server Module accepts power inputs from both DC and AC sources, to ensure your systems are never without power. When the DC resource is no longer available, the PSM automatically converts AC power to DC.

Residential DC Distribution Strategy

- Cooling and lighting account for 35% of AC electricity consumed in the US. Using solar PV, water to water GSHP, and LED lighting, the majority of electricity used in a home can be converted to DC. Thus, between 70-80% of the power consumption in a home can be provided via direct DC distribution.
- By minimizing solar PV/DC conversion to AC and then back to DC via net metering, the size of the solar PV system can be reduced by as much as 50%. The resulting savings can then be invested in a DC storage system which minimizes the use of net-metering. This would eliminate the 30-50% energy loss resulting from the DC-AC-DC conversion process for conventional net-metering.

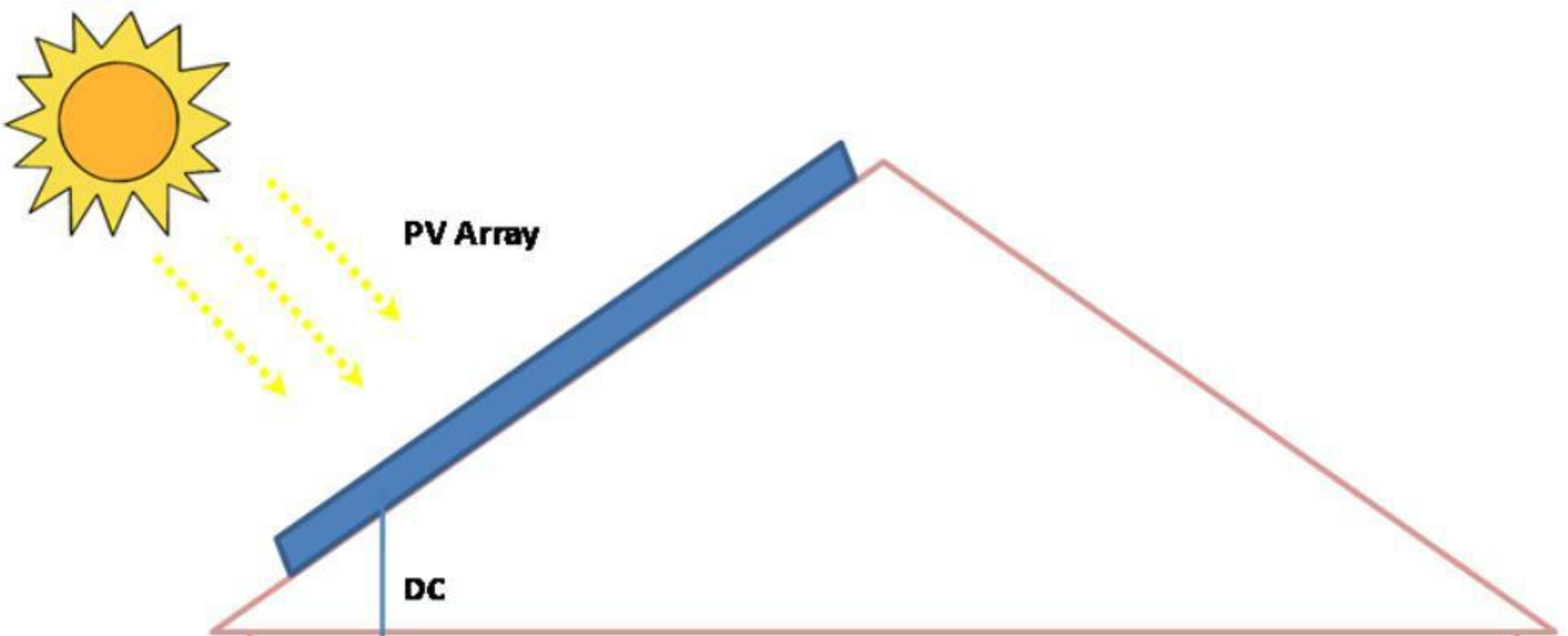
Dominant AC Electricity End-uses in the US

Table 1. Dominant AC electricity end-uses in the U.S. residential and commercial sectors showing energy use (quads) in 2010 and electricity usage rankings.

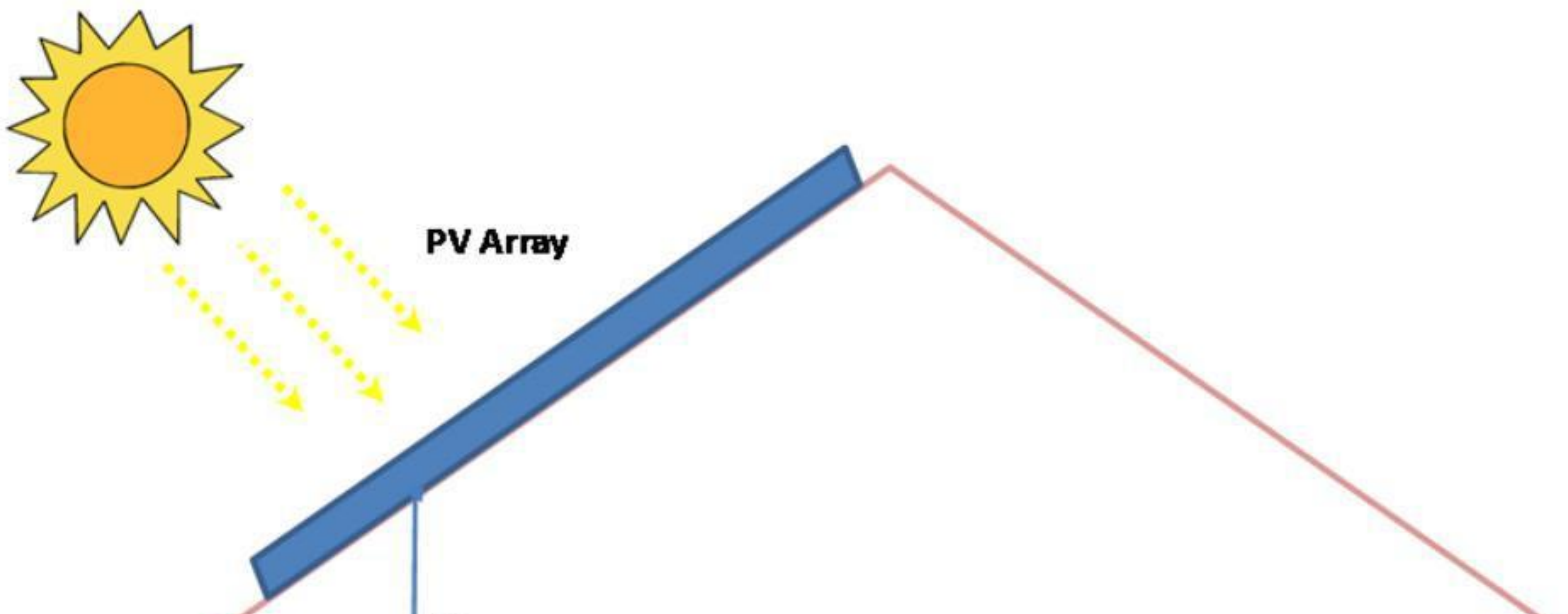
End Use	Residential (quads)	Ranking	% of sectoral total	Commercial (quads)	Ranking	% of sectoral total
Cooling	0.79	1	16%	0.5	3	11%
Lighting	0.72	2	15%	1.12	1	24%
Refrigeration	0.45	3	9%	0.23	5	5%
Sub-total	1.96		40%	1.85		39%
US Total	4.95			4.73		
Subtotal as percent of total	40%			39%		

(LBNL. Oct. 2011 - Catalog of DC Appliances and Power Systems)

AC Power System with Storage. Simple schematic of building with a net-metered PV system, electricity storage and an optional electric vehicle load. The inverter is bi-directional, allowing battery charging from the solar system during the day and from the grid at night.

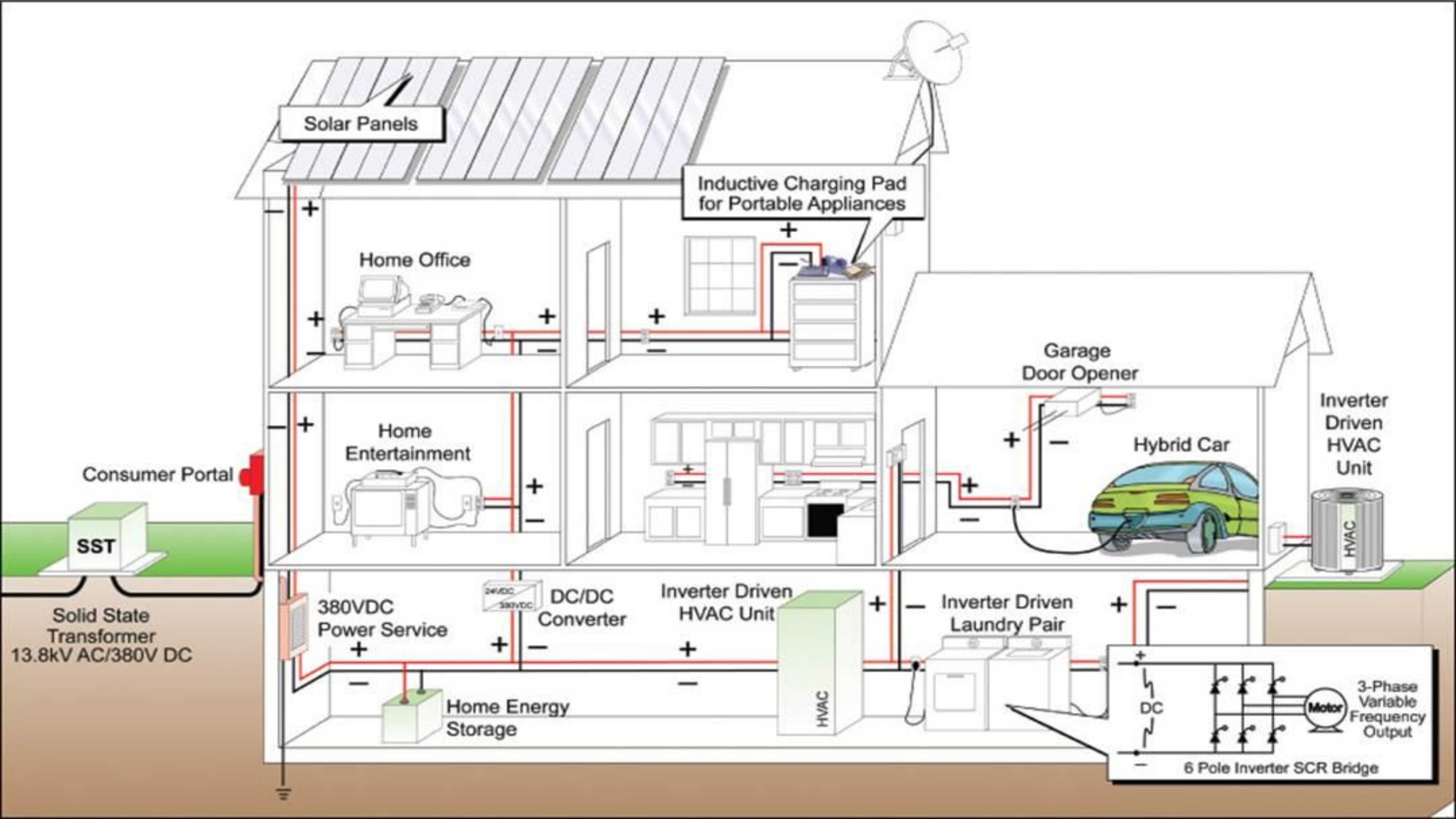


DC Power System with Storage. The loads in the building are the same as in Figure 4 above, except for the AC/DC power supplies. Power is distributed at 380VDC for high power loads and at 24VDC for low power loads.



Hybrid AC-DC Residential Systems

- Since a portion of the home will continue to use AC for washers and dryers, microwave, hair dryers, toasters, possibly freezers and refrigerators until the pricing for DC appliances comes down, a hybrid AC/DC wiring system could provide an alternative solution that adds considerable value.
- Yet another alternative would be to use DC-DC & DC-AC converters for a 24V DC low voltage delivery integrated with 380V DC distribution systems.



Solar Panels
Inductive Charging Pad for Portable Appliances
Home Office
Garage Door Opener
Inverter Driven HVAC Unit
Home Entertainment
Hybrid Car
Consumer Portal
SST
Solid State Transformer 13.8kV AC/380V DC
380VDC Power Service
24VDC
380VDC
DC/DC Converter
Inverter Driven HVAC Unit
HVAC
Inverter Driven Laundry Pair
Home Energy Storage
DC
Motor
3-Phase Variable Frequency Output
6 Pole Inverter SCR Bridge

Advanced Energy Storage (AES)

- Smart homes require state-of-the-art energy storage technologies for DC distribution systems that are independent of the grid. This is required in order to optimize energy efficiency by minimizing systemic thermal energy losses incurred for for converting DC-AC-DC via net-metering programs.
- DOE research led by the Argonne National Lab is exceeding lithium ion battery performance and capacity while reducing costs via the Joint Center for Energy Storage Research (JCESR).
- This AES technology will be available for use in electric vehicles and in modern DC distributive systems, e.g., DC microgrids for use in smart homes within 7 years.

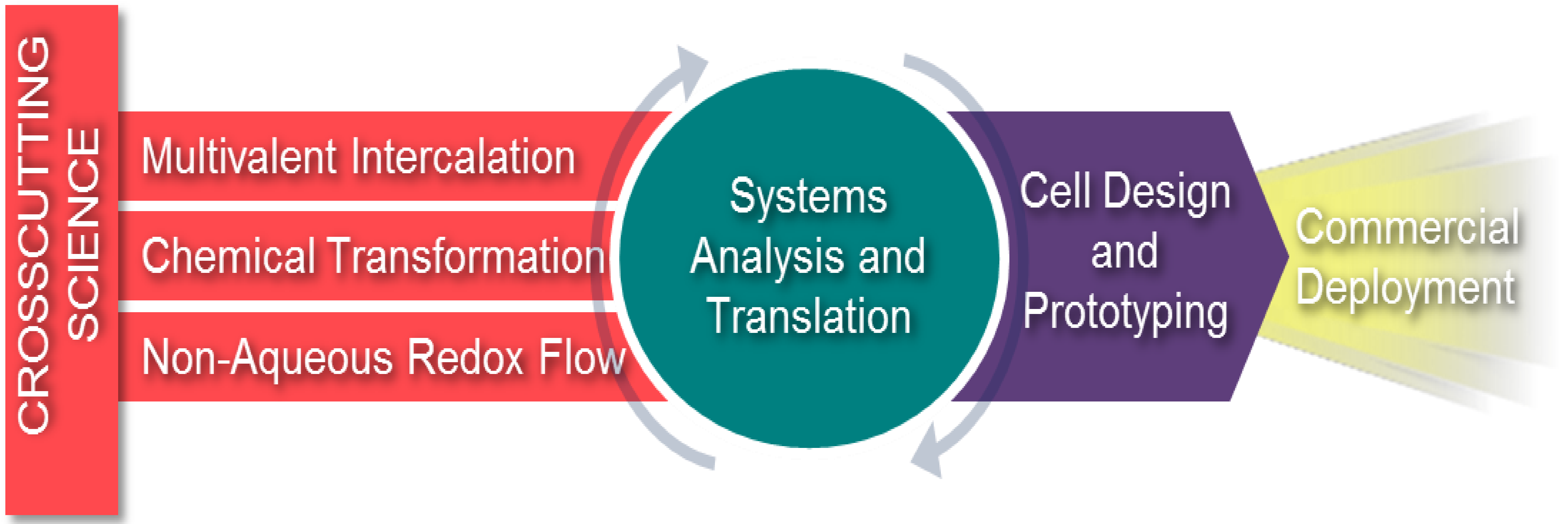
Joint Center for Energy Storage Research (JCESR)

- JCESR aims to go beyond today’s best Li-ion systems to provide **five times the energy storage at one-fifth the cost within five years**.
- Meeting this goal will require the discovery of new energy storage chemistries through an atomic-level understanding of energy storage phenomena and the development of universal design rules for battery performance.
- During the development of these AES technologies, lithium ion and other more cost competitive battery technologies can be used for 12-24 hour backup strategies to minimize energy inefficiencies due to DC-AC-DC net-metering systems.

Accelerating Scientific Research & Innovation

- JCESR will speed innovation by applying fundamental scientific advances of the last decade to battery R&D and uniting discovery science, materials design, battery system design, and advanced prototyping in a single highly interactive process.
- This approach integrates four key thrusts to address priority research challenges:
  - Electrochemical Storage Concepts
  - Crosscutting Science
  - Systems Analysis and Translation
  - Cell Design and Prototyping

Research Flow Chart



Electrochemical Storage Concepts

Focuses on three electricity storage concepts that are broader and more inclusive than the specific battery technologies now being pursued by the battery community:

- Multivalent Intercalation focuses on working ions, such as magnesium or yttrium, that carry twice or triple the charge of lithium and have the potential to store two or three times as much energy.
- Chemical Transformation is based on using the chemical reaction of the working ion to store many times the energy of today’s lithium-ion batteries.
- Non-aqueous Redox Flow is based on reversibly — changing the charge state of ions held in solution in large storage tanks; the very high capacity of this approach is well-suited to the needs of the grid.

Crosscutting Science

Employs forefront basic research techniques developed in the last decade to make new materials and characterize their performance at the atomic level for the three energy storage concepts.

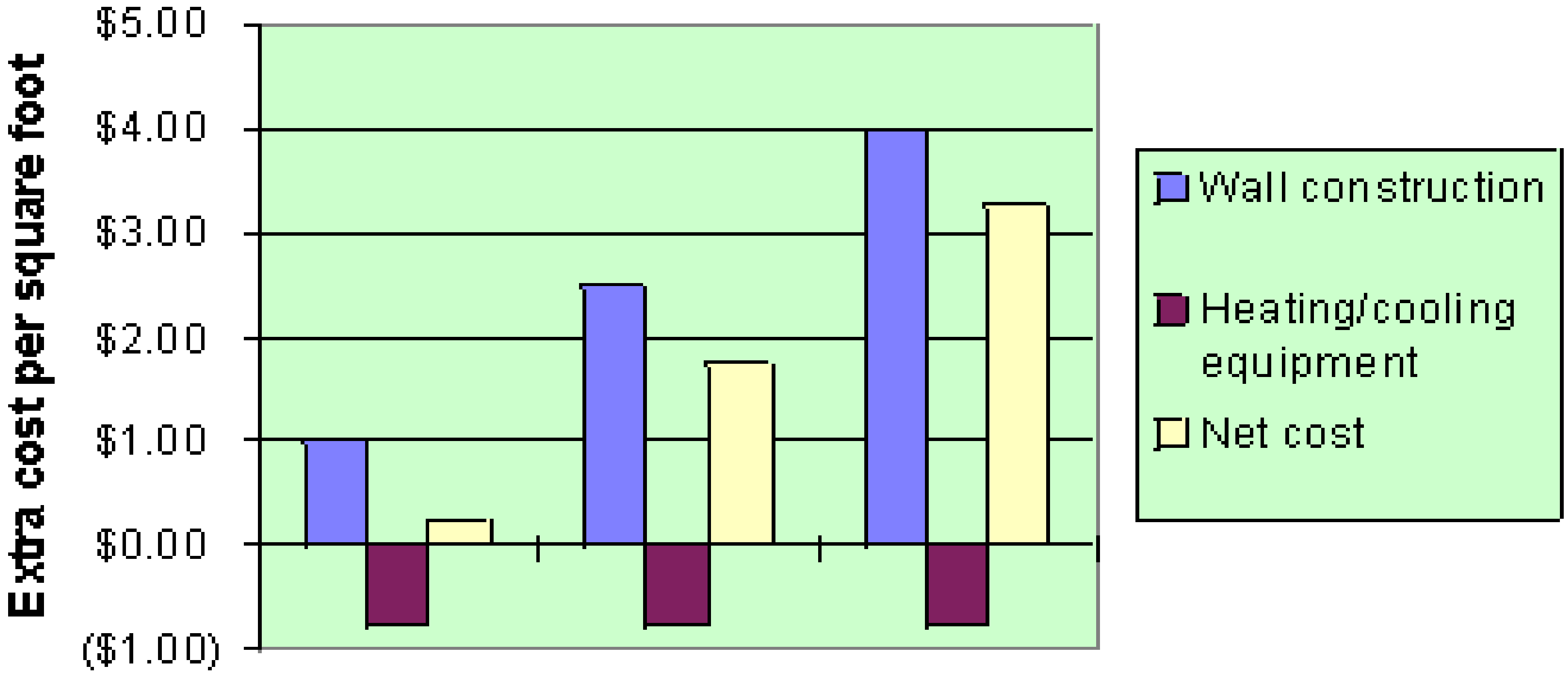
Systems Analysis and Translation

Designs virtual batteries on the computer, projects their performance, identifies shortcomings, and communicates results to the Science and Concept teams.

Cell Design & Prototyping

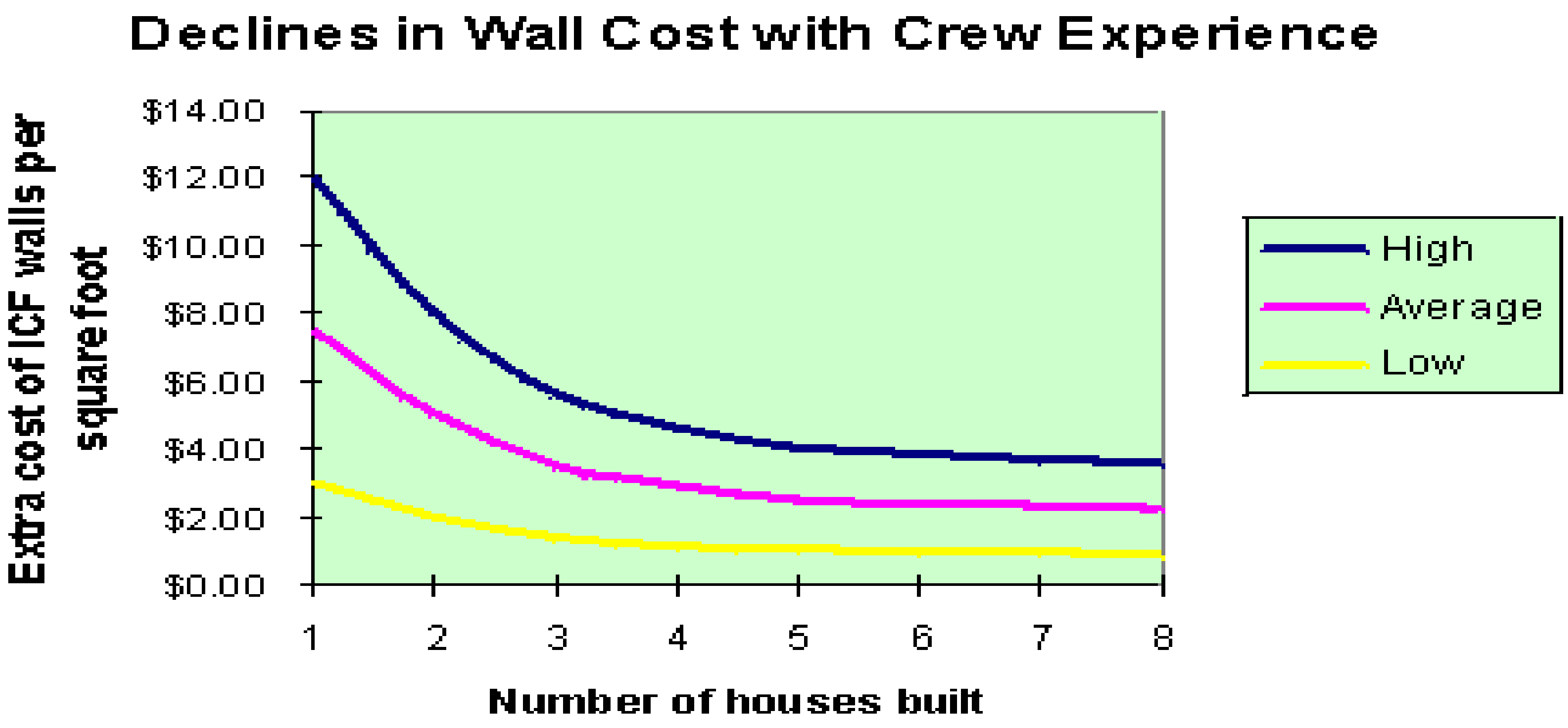
Delivers pre-commercial prototypes for grid and transportation applications.

ICF Construction Costs



Construction costs for walls vary with experience of crew,
type of ICF block and bracing system utilized, and design of structure.

Experienced ICF Crews



Using relatively large ICF blocks that require no assembly on-site and a conveyor belt system for moving ICF blocks for strategically designed homes that minimize cutting should allow for producing an ICF home for about the same price as stick-frame technology.

Energetically Modified Cement (EMC)

- Opportunities exist for replacing large portions of Portland Cement with lower cost chemically modified fly ash.
- Referred to as EMC, in conjunction with fiber reinforced polymers (FRP), higher educational institutions and the American Concrete Institute are currently evaluating a variety of polymer fibers including polyvinyl alcohol (PVA), nylon, and acrylic fibers.
- These polymer fibers, used in relatively small quantities, allow for reducing cracking and replacing a significant portion of reinforced steel in structures for engineered cementitious composites (ECC).
- In some cases, where materials and expertise is available, both labor and material costs can be reduced by as much as 30% for construction of state-of-the-art ICF structures.

ICF Bracing & Shoring Systems

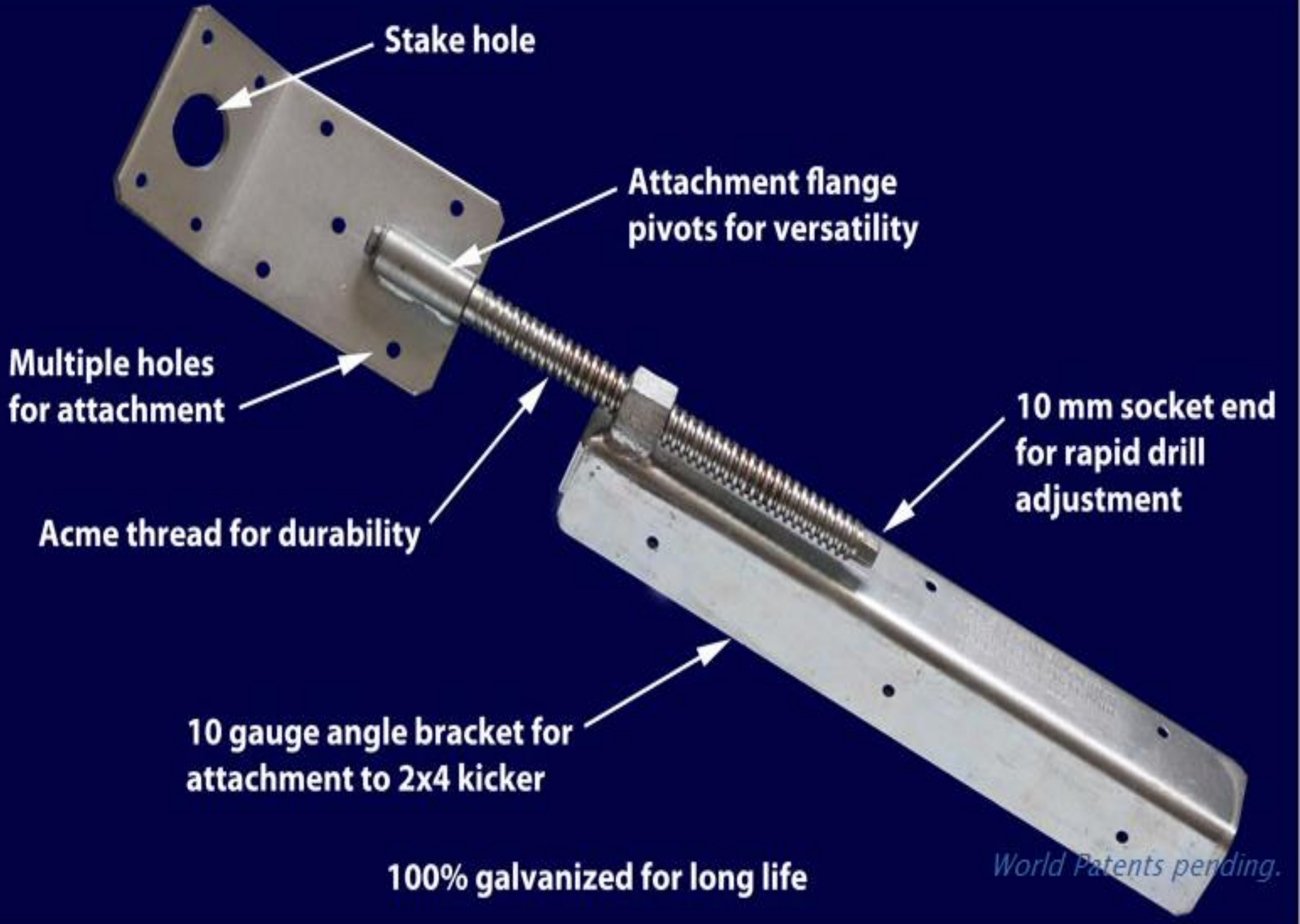
- State-of-the-art bracing/shoring systems and construction management will be developed to increase ICF production from 30 ft^2/man-hour ($0.67/$ft^2$ at $20/hour) for basic ICF blocks to potentially as high as 200 ft^2/man-hour ($0.10/$ft^2$ at $20/hour) for experienced crews using larger preassembled hinged web blocks with “corner” and “T” blocks and other innovations such as 4-way reversible technology.
- Higher productivity will also be aided by portable conveyor belts and/or panelization, innovative bracing and shoring, and state-of-the-art construction management. Man-hour rates are for complete ICF wall installation including staging, assembly, bracing, concrete pour, bracing removal, and cleanup. Conventional productivity is based mainly on crew experience, design and complexity of project, concrete mix design including EMC & ECC, and type of bracing systems used.

Zont® ICF Bracing System

- Quick & Simple
  - uses Zont® Braces
  - Zuckle® wall aligners
  - 2x4 studs
- Inexpensive – 10% of the cost and 90% lighter than vertical steel bracing
- Straight walls & height adaptable
- Green building concept
- Easy to disassemble & transport

Zuckle™ Wall Aligner

Finally. A wall aligner specifically designed for ICF walls. Only 3.6 pounds, just half the weight of conventional turnbuckles. And fast adjustment with an electric drill.



Zont Twist™ Bracket

The Zont Twist™ locks the 2x4 walers and strongbacks against the ICF wall to flatten the wall horizontally and vertically.

The plastic cam is twisted counterclockwise to quickly lock the lumber, reducing the installation time by one half. The cam is designed so that any wall settlement will tighten the lumber against the wall.

World Patents pending.

Straighter Walls

HoriZONTal walers are the first contact with the wall, straightening first in the horizontal direction.

Compare this with conventional vertical braces where the first contact is vertical, leading to a wavy horizontal alignment.

Economic

Zont™ bracing is approximately 10% the cost of vertical bracing.

Why rent conventional braces when you can buy for the same price?

Fast to Install

A 'twist' of the wrist quickly locks the horizontal waler and vertical strongback in position.

Light Weight

Zont™ waler brackets and Zuckle™ wall aligners weight 11% the weight of conventional vertical bracing.

79 lbs

9 lbs

Height Adaptable

Brace short stem walls or 20' tall walls.

Just add another row of Zonts™ and walers for every five feet of wall.

Easy Bucking

Window and end of wall bucks are easily reinforced as there is no vertical braces in the way.

Green

Use site available 2x4s, save on delivery and storage costs.

Easy to Transport

Fit 15 Zont™ braces (30 Zonts™ and 15 Zuckles™) into a recycle bin and 5 gallon bucket.

Try that with 15 conventional braces.

ZONT TWIST BRACING

FOR CATWALK HEIGHT LESS THAN 6'

9 Build rest of wall. Attach top row of Zonts™ at top of wall on left side of strongback. Use 8" extension on impact drill to screw around strongback. Place 2x4 walers in Zont, then twist cam to lock bracing to ICF wall.

10 Align wall by plumbing corners with 6' spirit level. Attach 3/4" blocks on outside end of each face, run stringline between. Use 8" hex extension, 10 mm driver & electric drill to adjust Zuckles™ & align top edge 3/4" from stringline. Replumb wall before, during, after pour.
Always **PUSH** wall, never pull.

8 Screw plywood gussets to each strongback to support 2x10 plank. Conform to local code. Use four #10 or #12 screws for adequate shear strength.

7 Solidly drive two stakes into ground at different angles for maximum resistance. Screw stakes to base of kicker. For slabs, use two 24" 2x6s jointed to form an "L". Adjust Zuckle™ to plumb strongback (fine adjustment is done later with stringline).

6 Attach Zuckle™ to top of kicker, screw attach to strongback (or plywood gusset) at 45° angle. The higher the attachment, the easier to plumb wall.

Tools
Electric drill (impact)
Zuckle™ driver (supplied by Fab-Form)
8" drill extension
Skill saw
Hammer for driving stakes
Spirit level for plumbing corners
Stringline for aligning top of wall

IMPORTANT
1 Always **PUSH**, never pull wall
2 **Vibration** can loosen cams, check tightness
3 Never leave wall unbraced (wind damage)
4 Zont™ Bracing is a wall alignment system, ensure catwalk complies to local code

ZONT TWIST BRACING

FOR CATWALK HEIGHT GREATER THAN 6'

11 Align wall by plumbing corners with 6' spirit level. Attach 3/4" blocks on outside end of each face, run stringline between. Use 8" hex extension, 10 mm driver & electric drill to adjust Zuckles™ & align top edge 3/4" from stringline. Replumb wall before, during, after pour.

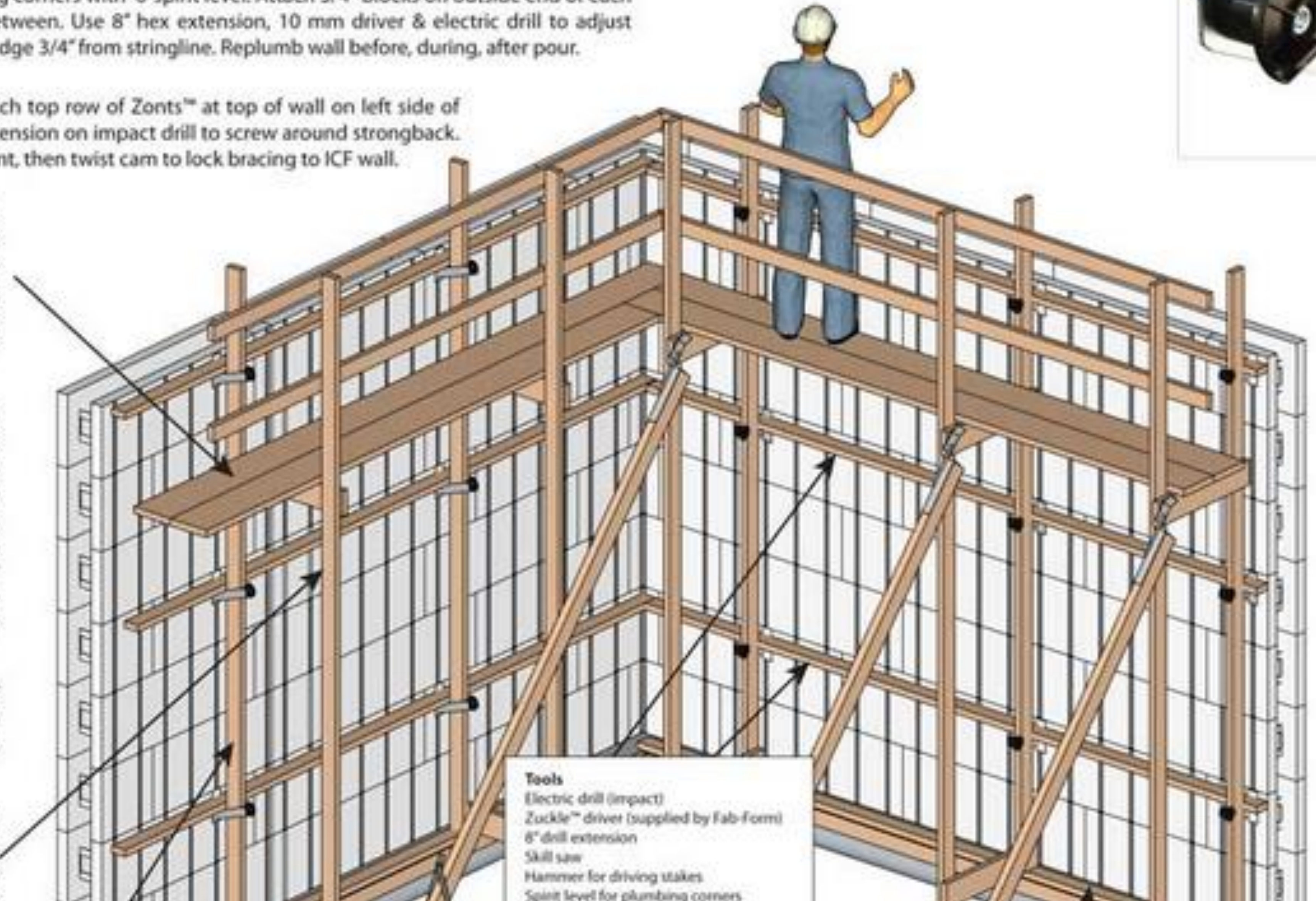
10 Build rest of wall. Attach top row of Zonts™ at top of wall on left side of strongback. Use 8" extension on impact drill to screw around strongback. Place 2x4 walers in Zont, then twist cam to lock bracing to ICF wall.

9 Install pairs of 2x10s around the perimeter, ensuring all ends are supported completely. Attach 2x4 top rail at least 36" above catwalk with mid rail half way between.

8 Solidly drive two stakes into ground at different angles for maximum strength. Screw stakes to base of kicker. For slabs, use two 24" 2x6s jointed to form an "L". Adjust Zuckle™ to plumb strongback (fine adjustment is done later with stringline).

7 Attach Zuckle™ to top of 2x4 kicker, then screw attach assembly to top 2x6 at 45° angle.

6 Locate a second strong-back 20" outside the first. Hold in position with pairs of 2x6s 28" in length



Tools
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8" drill extension
Skill saw
Hammer for driving stakes
Spirit level for plumbing corners

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4 Zont™ Bracing is a wall alignment system, ensure catwalk complies to local code

ORM
IES LTD.
orm.com
3-FAST (3278)

Large Rigid ICF Blocks Minimize Bracing

- Some ICF blocks (Polycrete) are manufactured with reinforcing steel mesh embedded within the expanded polystyrene (EPS). This steel wire mesh incorporated within the EPS panel results in extreme strength and unmatched wall stability.
- These 2’x8’ ICF products are capable of resisting lateral pressures of 1600 lbs/ft^3 (75kPa) during concrete pours.
- However, this technology is expensive and it is not currently manufactured in the US. Thus, transportation costs for shipping from the manufacturer in Eastern Canada, particularly to Western US cities would be substantial.

NUDURA ICF Innovations

- **DURALOK Technology™-** A patented Fastening Strip securely locks forms into place with a patented reversible triple tooth interlock eliminating float and compression and the need to wire forms. The DURALOK Technology™ has embedded web/fastening strips that run the full 18-inch height of each and every web, ensuring the ICF forms do not compress during concrete placement and provide a continuous fastening strip for finish materials.
- **DURAFOLD Technology™-** Their Patented Hinged Web allows NUDURA ICF Products to be shipped flat, allowing for 40% more product on a truck compared to other ICF products.

NUDURA ICF Innovations cont.

- **DURAMAX Technology™-** NUDURA® Standard Forms offer DURAMAX Technology™ the largest standard Insulated Concrete Form in the industry measuring 1.5' X 8', allowing the placement of 12 sf of wall area in one building step. Building with DURAMAX Technology™ results in faster installation times, less waste and reduced seams, compared to other ICF block manufacturers.
- **4-WAY REVERSIBLE System -** Their patented foam interlock allows the form to be 4 way reversible, almost eliminating waste. Eliminates left and right corners which allow NUDURA ICF Forms to be used in twice as many scenarios as no reversible forms.

Cost of ICF Construction

- Houses built by experienced ICF crews cost between 2-12% more than wood frame houses of the same design.
- Typical new US homes cost $80-100 per square foot. Building walls of conventional ICF blocks adds $1.00-$4.00 to this figure. But since ICF houses are more energy-efficient, the heating and cooling equipment can be downsized substantially in comparison with a stick-frame home.

Cost of ICF Construction cont.

- This can cut the cost of the final house by an estimated $0.75 per square foot. So the net extra cost is about $0.25-$3.25 for conventional ICF construction.
- For experienced ICF crews using state-of-the-art hybrid block-panel technology and innovative construction management, the cost of building superior ICF homes can be substantially reduced (by over 50%), thereby constructing a ZNE home for about the same cost as a stick-frame home (plus the cost of solar energy systems which can be offset with sweat equity programs).

ICF Block vs. Panel Technologies

- Though ICF panel manufacturers can installers can increase sqft/man-hour productivity to as much as 140, innovative ICF block manufacturers are developing hybrid block-panel technologies that can potentially exceed 200 sqft/man-hour.
- This will allow for reducing labor costs by as much as 80% in comparison with stick-frame construction while providing superior quality and workmanship, unprecedented energy efficiency and durability, and at a cost comparable to stick-frame construction.
- ICF hybrid block-panel designs range in size from 2’x8’ to 4’x8’ with 1’x8’ blocks also available. Some ICF builders are assembling these blocks into panels in the shop, thereby further reducing construction time, particularly in inclement weather.

Benefits of ICF Block Panelization

- Can extend the building season, reduce travel to jobsite by 60% or more, and most tools are left at the shop. Construction of ICF block panels in the shop can dramatically enhance productivity. Tool theft drops because most tools are left at the shop.
- The waste factor decreases significantly as well. Everything is put into in bins and sorted by size, where otherwise it would be discarded as garbage. Another benefit is a cleaner jobsite.
- Time management is a factor. On days when crews finish early they can return to the shop to start panelizing the next job. The main advantage of panelization is the decrease in cycle times. If you're doing a fast build-out on a production scale, it can cut your costs down significantly.
- The construction process is easier with panels as well. If footings are not perfect, panelizing lets you set one corner, and shim it. It's easier with larger, more rigid panels. It's also easier to check diagonals on frost walls, or walkout basements. Several contractors claim that panelized walls are more rigid during pours as well.

Strategic Structural Design

- In conjunction with using larger hybrid ICF block and panelization technologies, strategically designing structures with 2’ high window sills and 4’ high windows can substantially reduce cutting and thereby further enhance productivity when using 2’x8’ and 4’x8’ sized panels.
- For 9’ walls and 7’ doors, a 1’x8’ panel would be ideal in addition to 2’x8’ and 4’x8’ sized panels.
- Wall angles should be kept to 45 and 90 degrees, and most bay windows and circular walls will probably need to be constructed on site rather than in the shop.
- ICF footing-wall combinations provide an opportunity to substantially enhance productivity if the structure is designed accordingly.

Integrated Footing & Foundation Forms

Panels for erection of foundation with pre-installed dowels

Two levels of components have now been installed. The Zont bracing is attached to align the wall and fix into exact location with stakes at the base of each vertical strongback.

The catwalk has been installed using plywood gussets. Kickers to align the wall are located 6' on centre.

An electric drill is used to adjust the Zuckle™ to align the wall to the stringline.

The footings are protected from ground moisture on the bottom, sides and top with the Fastfoot® membrane.

Concrete pour is almost complete, top portion of the wall is about to be filled. Note the use of Fastfoot® on all internal footings.

Concrete pour is almost complete, top portion of the wall is about to be filled. Note the use of Fastfoot® on all internal footings.

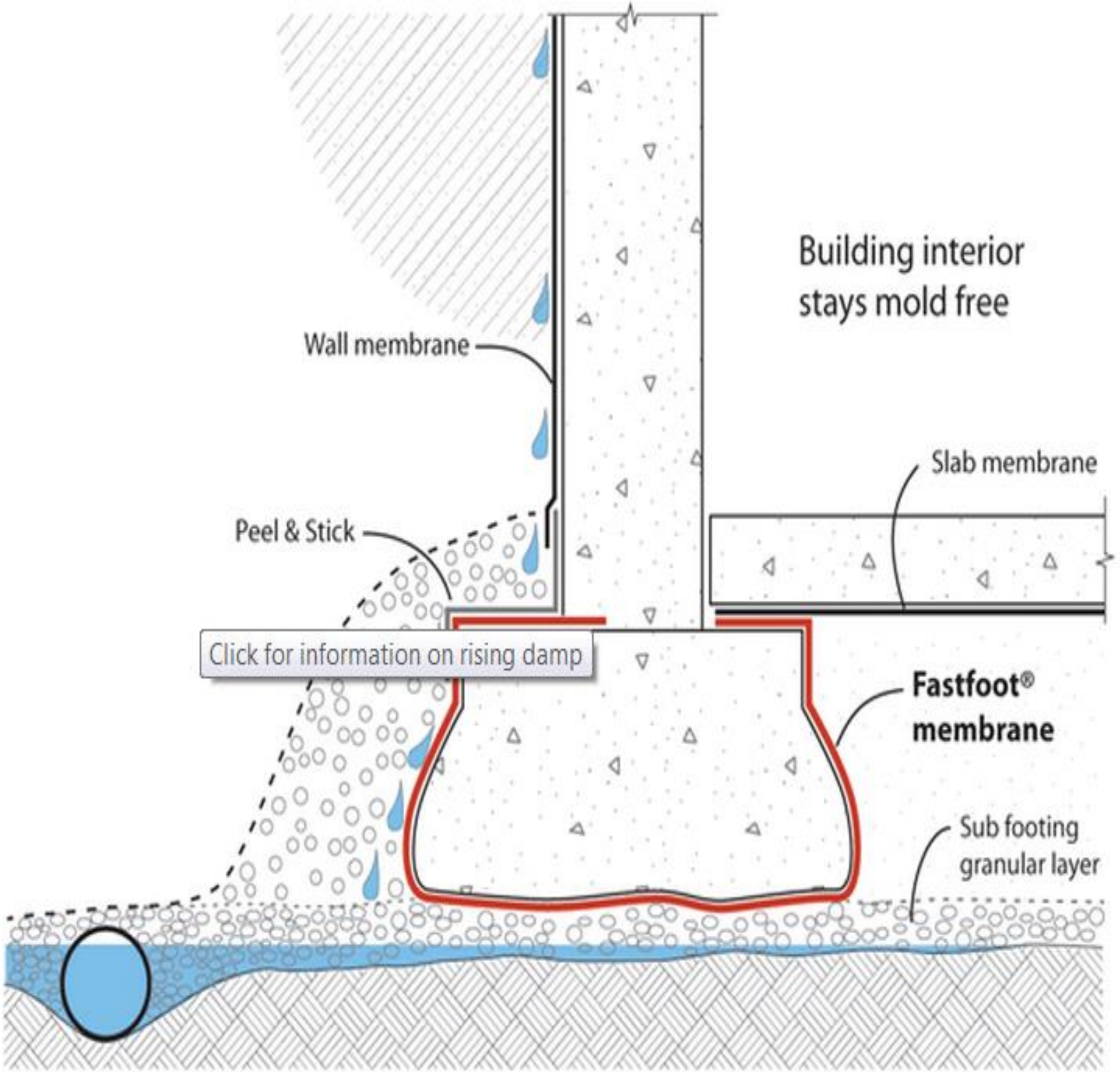
Concrete pour is complete, with the top of the wall being screeded by the Naikoon crew.

Prevents Rising Damp

Concrete is 'hygroscopic', wicking up ground moisture which leads to a damp and moldy interior.

Fastfoot® is a damp proof membrane, preventing ground moisture wicking into the footing concrete, providing a drier, healthier indoor environment.

Click image for information on rising damp.



Prevents Ground Water Contamination

Fastfoot® is a closed form, preventing cement fines from entering the water table.

Stronger Concrete

As the picture above shows, Fastfoot® prevents the footing concrete from being contaminated by mud and water, leading to a stronger concrete.

In the summer, Fastfoot® prevents rapid evaporation of moisture in the sides and bottom of the footing. This ensures adequate moisture for proper hydration of the cement particles.

FastFooting – HDPE Waterproofing

- Cost effective footings
- No lumber required
- High density polyethelene (HDPE) FastFooting material remains in place
- Provides waterproofing for concrete footings
- Quick and easy to install, level, and adjust to string line
- Ideal for use in conjunction with twisted steel fibers (helix micro-rebar) which eliminates need for conventional rebar and steel mesh

Self-Consolidating Concrete (SCC)

- After identification, the defects in concrete in Japan were found to be mainly due to
  - a) high water cement ratio to increase workability,
  - b) poor compaction mostly happened due to the need of speedy construction in 1960s–70s,
- Professor Hajime Okamura envisioned the need of a concrete that is highly workable and does not rely on the mechanical force for compaction.
- During the 1980s, Professor Okamura and his PhD student Kazamasa Ozawa (currently professor) at the University of Tokyo, Japan developed a concrete called Self Compacting Concrete (SCC) that was cohesive but flowable and took the shape of the formwork without use of any mechanical compaction. SCC is known as self-consolidating concrete in the United States.

SCC Characteristics – 50% Labor Reduction

- Extreme fluidity as measured by *flow*, typically between 650–750 mm on a flow table, rather than slump (height)
- No need for vibrators to compact the concrete
- Placement being easier.
- No bleed water, or aggregate segregation
- Increased liquid head pressure, can be detrimental to safety and workmanship
- SCC can save up to 50% in labor costs due to 80% faster pouring and reduced wear and tear on formwork.

Polycarboxylate Superplasticizer

- As of 2005, self-consolidating concretes account for 10–15% of concrete sales in some European countries. In the US precast concrete industry, SCC represents over 75% of concrete production. 38 departments of transportation in the US accept the use of SCC for road and bridge projects.
- This emerging technology is made possible by the use of polycarboxylates plasticizer instead of older naphthalene-based polymers, and viscosity modifiers to address aggregate segregation.
- Polycarboxylate ether superplasticizer (PCE) or just polycarboxylate (PC), work differently from sulfonate-based superplasticizers, giving cement dispersion by steric stabilization, instead of electrostatic repulsion. This form of dispersion is more powerful in its effect and gives improved workability retention to the cementitious mix.

Polycarboxylate Ether Superplasticizer

- The new generation of this kind of admixture is represented by polycarboxylate ether-based superplasticizers (PCEs).
- With a relatively low dosage (0.15–0.3% by cement weight) they allow a water reduction up to 40%, due to their chemical structure which enables good particle dispersion.

PCE Chemical Structure

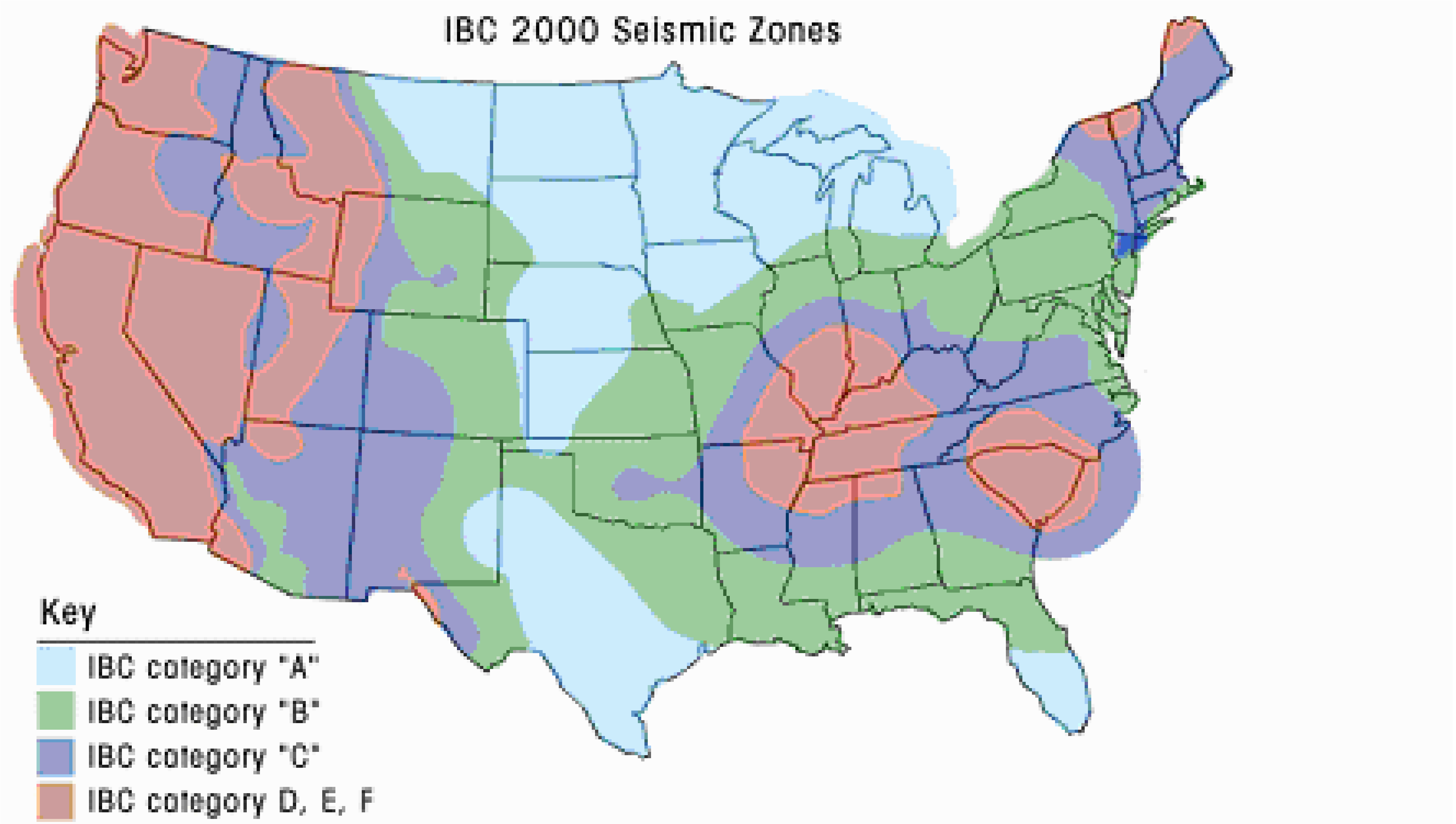
- PCEs are composed by a methoxy-polyethylene glycol copolymer (side chain) grafted with methacrylic acid copolymer (main chain).
- The carboxylic acid COONa dissociates in water, providing a negative charge along the PCE backbone.
- The polyethylene oxide (PEO or MPEG) group affords a not uniform distribution of electron cloud, which gives a chemical polarity to the side chains.
- The number and the length of side chains are flexible parameters that are easy to change. When the side chains have a huge amount of EO units, they lower with their high molar mass the charge density of the polymer, which enables poor performances on cement suspensions.
- To have both parameters on the same time, long side chain and high charge density, one can keep the number of main-chain-units much higher than the number of side-chain-units

PCE Mode of Action

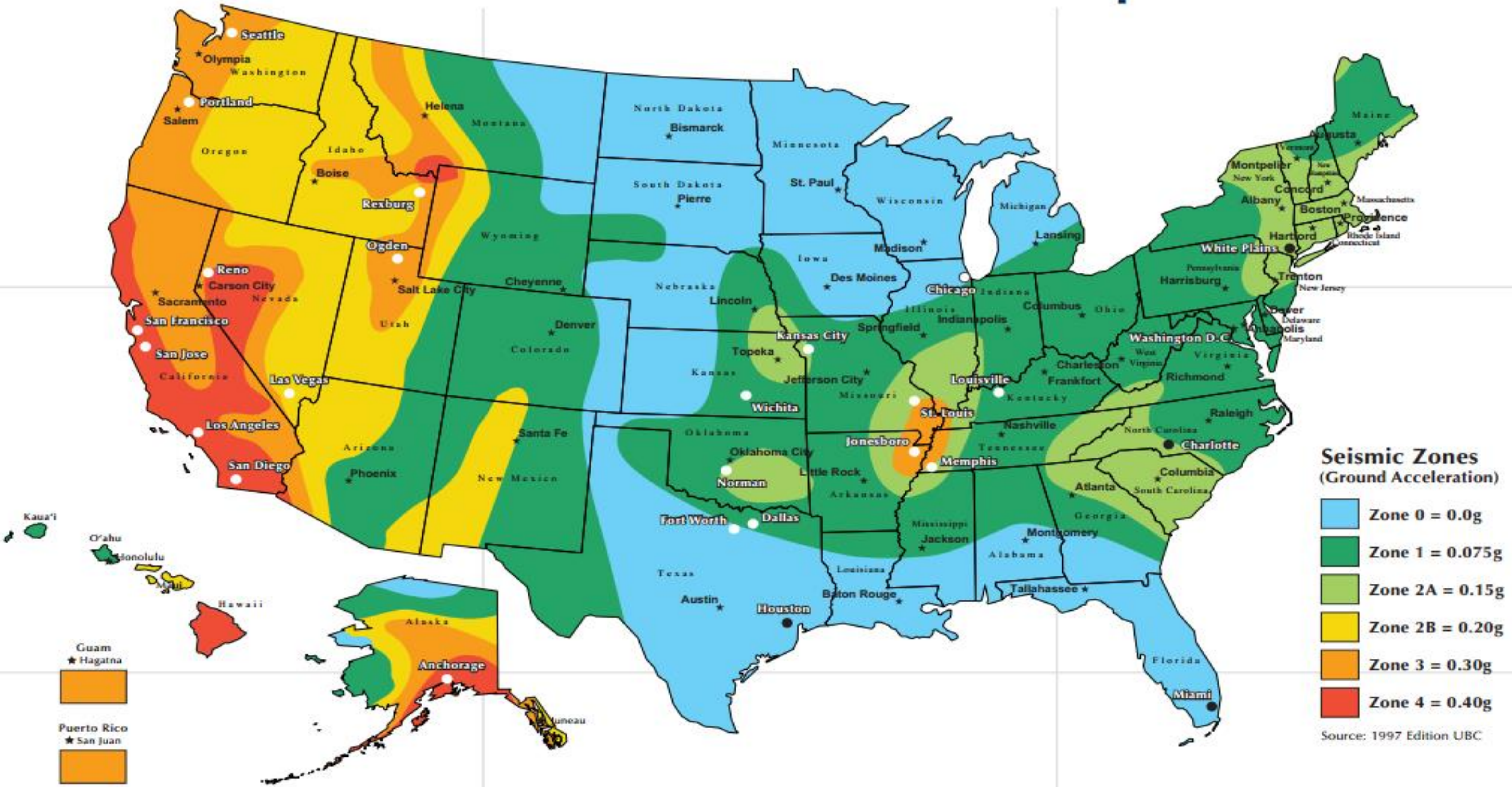
- PCE's backbone, which is negatively charged, permits the adsorption on the positively charged colloidal particles.
- As a consequence of PCE adsorption, the zeta potential of the suspended particles changes, due to the adsorption of the COO- groups on the colloid surface.
- This displacement of the polymer on the particle surface ensures to the side chains the possibility to exert repulsion forces, which disperse the particles of the suspension and avoid friction.
- These forces can be directly detected by the use of the atomic force microscopy (AFM), working with model substances in liquid environment.

Seismic Zones & Steel Reinforcement

- Depending on the seismic activity for a given geographical region, seismic zones are assigned according to various agencies including the International Building Code (IBC) and the Uniform Building Code (UBC).
- These seismic zones determine the amount and type of steel reinforcement required to meet local building codes for concrete mixes, particularly for specific soil types.
- By calculating steel reinforcement requirements for specific locations and building types, the volume and expense of steel reinforcement can be minimized in conjunction with the mix design (portland cement and pozzolanic hybrid mixes, etc.) and volume of concrete specified.


IBC 2000 Seismic Zones
Key
IBC category "A"
IBC category "B"
IBC category "C"
IBC category D, E, F

United States Seismic Zones Map



Steel Fiber Reference Documents

- ACI 302 Guide for Concrete Floor and Slab Construction
- ACI 360 Design of Slabs on Ground
- ACI 544 3R Guide for Specifying, Proportioning, Mixing, Placing, and Finishing
- Steel Fiber Reinforced Concrete
- ACI 506 Guide for Shotcrete
- ASTM A820 Standard Specification for Steel Fibers for Fiber-Reinforced Concrete
- ASTM C 94 Standard Specification for Ready-Mixed Concrete
- ASTM C 1609 Standard Test Method for Flexural Toughness and First-Crack Strength
- of Fiber-Reinforced Concrete
- ASTM C 1116 Standard Specification for Fiber-Reinforced Concrete and Shotcrete
- ASTM C 1399 Standard Specification for Fiber-Reinforced Concrete and Shotcrete

Helix Micro Rebar Description

- Helix 5-25 Micro-Rebar reinforced concrete consists of two materials, as described in Sections 3.1 and 3.2 of ER-279.
  - 3.1 Product Information: Helix 5 .. 25 Micro-Rebar is made from cold drawn, deformed wire complying with ASTM A 820, Type L The steel wire has a ten slle strength of 275 ksi +/~ 15 ksi (1850 MPa +/ .. 150 MPa) and a minimum of 3 *g/m²* zinc coating. The length (I) is 1.0 inch +/~ 0.1 inch (25 mm +/ .. 0.004 mm), equivalent diameter is 0.020 inch +/-0.007 inch (0.5 mm +/- 0.02 mm), and cross sectional area is 0.003 square inches (0.196 mm^2). Each Helix Micro-Rebar has a minimum of one 360-degree twist. Helix Micro- Rebars are packaged in 22.5 pound (10 kg) boxes, 4S-pound (22.5 kg) boxes or 24S0-pound (1100 kg) bags.
  - 3.2 Normal Weight Concrete with a minimum 28 day compressive strength of 3,000 psi (20.66 MPa).

Steel Fiber can Reduce Labor by over 50%

- Twisted steel micro-rebar (TSMR) or other steel fibers and monolithic pouring systems allow for reducing or eliminating rebar and mesh steel reinforcement.
- TSMR fibers are one inch long strands of 245 KSI carbon steel electroplated with zinc for corrosion resistance.
- The twisted shape resists tension similar to the tension required to pull out nails vs. screws.
- The TSMR fibers can be effectively used as an admix in engineered cementitious composites that are lightweight with increased compressive strength and durability.

Seismic Zone IBC-C/UBC-2B for Boise, ID

Dosage of Helix 5-25 Based on Footing and Rebar Configuration (lb/yd^3)

Rebar Configuration	Steel reinforcement ratio (in^2/ft)	Footing thickness				
		8 inches	10 inches	12 inches	14 inches	16 inches
#4 at 6"	0.40	Note 4	33.5	30.1	27.4	25.0
#4 at 8"	0.30	27.4	25.1	22.9	19.0	17.3
#4 at 10"	0.24	22.2	20.4	16.8	15.1	13.7
#4 at 12"	0.20	18.7	15.4	13.9	12.6	11.5
#5 at 8"	0.47	Note 4	Note 4	34.9	Note 4	29.0
#5 at 10"	0.37	33.1	Note 4	27.9	25.4	21.5
#5 at 12"	0.31	27.9	25.8	23.5	19.6	17.8

Notes:

1. Table is based on concrete with a minimum specified compressive strength of 3,000 psi.

2. Table values are calculated using a concrete cover for the rebar of 3 inches from the bottom of the footing
3. If rebar is placed at the center of the thickness, Helix dosage may be multiplied by a factor of 0.75

ICF Structures & Suspended Slabs

- Steel fiber can be used in suspended slabs over occupied areas if it only replaces the temperature shrinkage reinforcement and the shear steel in the concrete beam sections.
- Flexural steel rebar in the supporting concrete beams cannot be replaced by steel fiber, but their numbers and size can potentially be reduced by a hybrid design that blends conventional rebar and steel fiber.

IAPMO Uniform EC - Twisted Steel Micro-Rebar

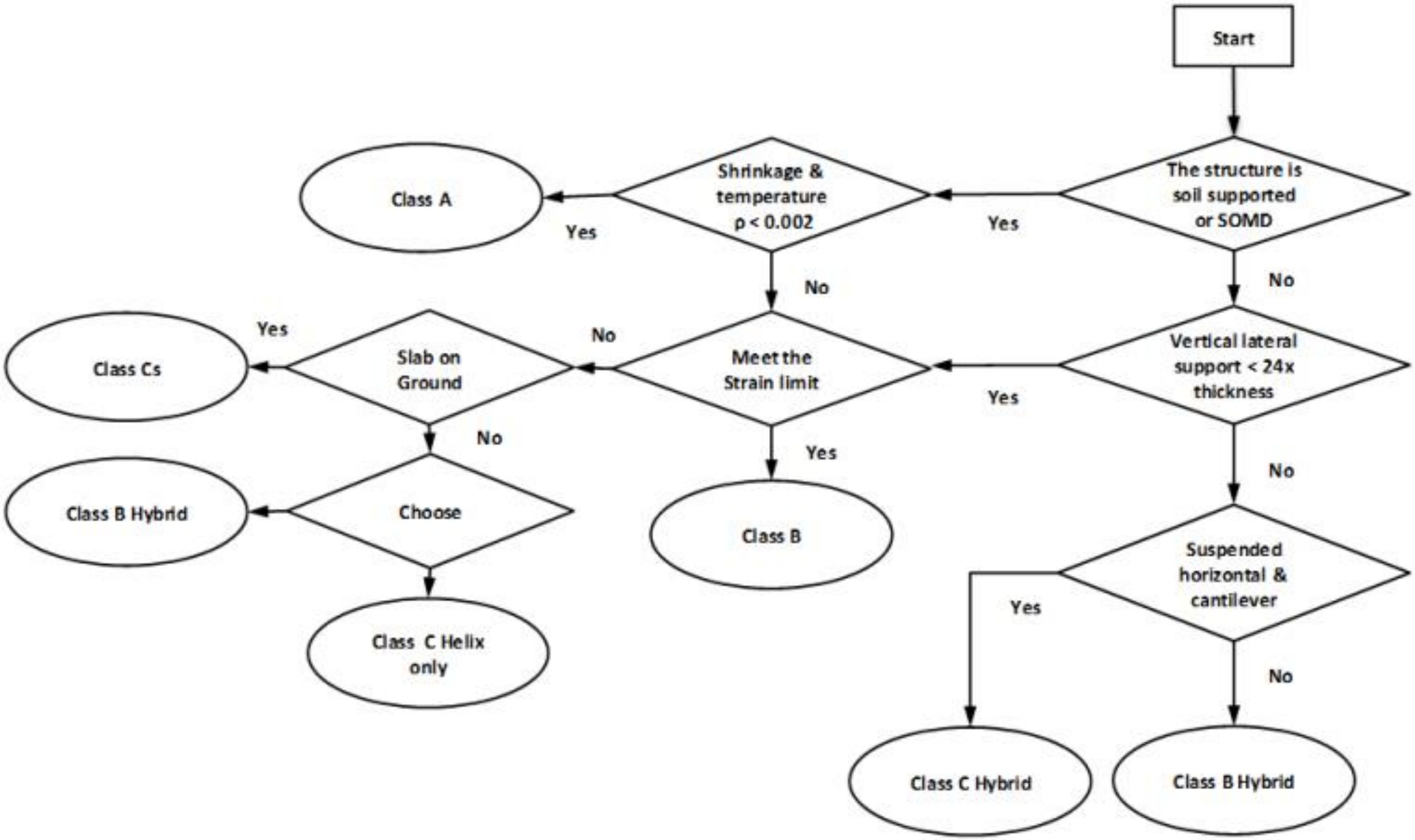
INTERNATIONAL ASSOCIATION OF PLUMBING AND MECHANICAL OFFICIALS, UNIFORM EVALUATION SERVICES

EVALUATION CRITERIA FOR TWISTED STEEL MICRO-REBAR (TSMR) IN CONCRETE

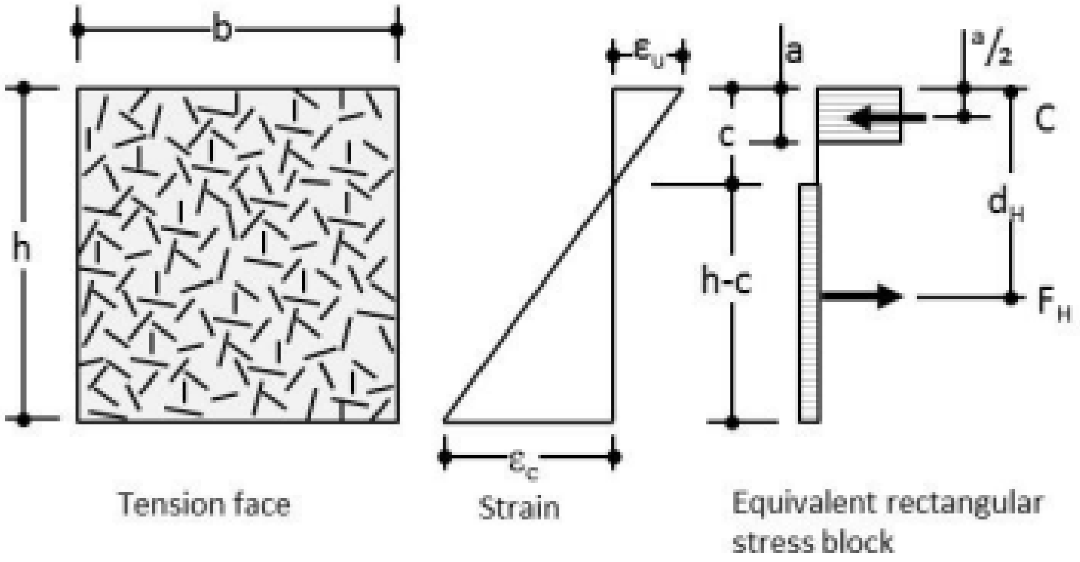
EC 015 – 2013
(Adopted - December 2013)

1.0 INTRODUCTION

1.1 **Purpose**: The purpose of this evaluation criteria is to establish requirements for Twisted Steel Micro Rebar (TSMR) in an independently reviewed evaluation report under the 2012 and 2009 *International Building Code*® (IBC) and the 2012 and *International Residential Code*® (IRC). Bases of recognition are IBC Section 104.11 and IRC Section R104.11.



ER-279 **Figure 1 – Helix Design Class Selection Flow Chart**



$$c = \frac{-h + \sqrt{h^2 + (1-\beta)\frac{8M}{0.85f'_c\beta b}}}{2(1-\beta)}$$

$$A_{s\ req'd\ center\ of\ tension\ zone} = \frac{0.85f'_c b\beta c}{f_y}$$

Where

M is the required moment capacity of the section calculated per ACI 318. If considering a previously designed section, $M = \phi M_n$. Otherwise, $M = M_u$, where M_u is the factored moment of the section based upon loading.

A_s is the area of steel required at the center of the tension zone (per section 4.6.1)

$F_H = A_s \times f_y$

f_y is the specified yield strength of the reinforcement

Figure 2: Helix Force Equilibrium and Strain Compatibility Diagram

Class A (Slab) Micro-rebar Dosage

HELIX™

Equivalent Helix Dosages for Fully Supported Slabs – CLASS A (US Customary Units)

Table 1 – Common Welded Wire Mesh Arrangements

Mesh Designation		Min. Helix Dosage Reqd. (lb/yd^3)				
		4 inch slab	5 inch slab	6 inch slab	7 inch slab	8 inch slab
6x6	W1.4xW1.4	9.0	9.0	9.0	9.0	9.0
6x6	W2.0xW2.0	9.0	9.0	9.0	9.0	9.0
6x6	W2.9xW2.9	9.0	9.0	9.0	9.0	9.0
6x6	W4xW4	13.5	9.0	9.0	9.0	9.0
4x4	W2.9xW2.9	13.5	10.0	9.0	9.0	9.0
6x6	W5.5xW5.5	15.0	13.5	10.0	9.0	9.0
4x4	W4xW4	18.0	13.5	13.5	10	9.0
4x4	W5.5xW5.5	25.0	18.0	15.0	13.5	13.5

Table 2 – Common Single Layer Rebar Arrangements

Helix Micro-rebar Replacement & Dosage

- The following are portions of design tables used to determine required dosage of micro reinforcement:
  - (a) the total number of micro reinforcement required to replace a given area of conventional reinforcing bars varies with concrete strength and design class;
  - (b) the micro reinforcement dosage is based on the required number of micro reinforcement per unit area.
- The method and models that serve as its basis have been validated with third-party testing, full-scale field testing, and peer reviews by structural engineers.

(a)

Table 1: Helix Micro-rebar Replacement

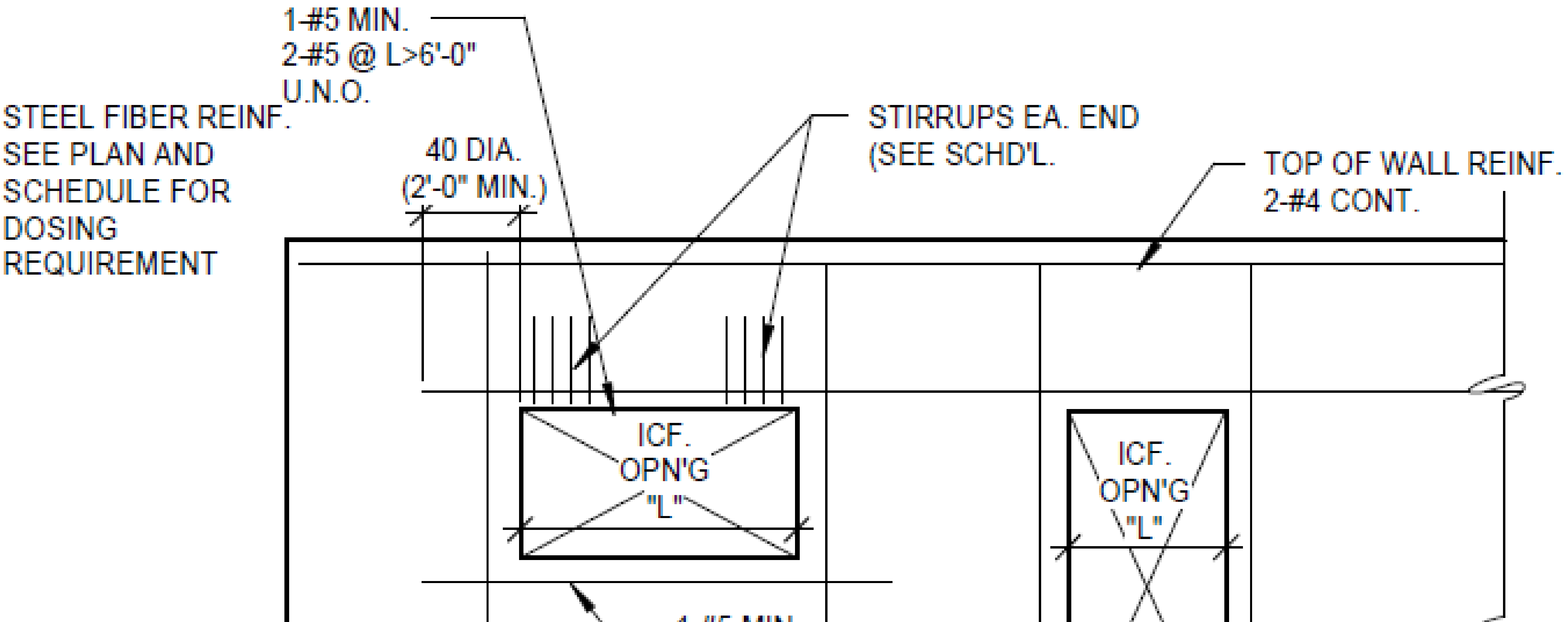
Fy = 60 ksi	Nominal number of Helix Micro Rebar required - Imperial			Fy = 500 Mpa	Nominal number of Helix Micro Rebar required - Metric		
Nominal area of steel in tension As (in^2/ft)	3000 psi	4000 psi	5000 psi	Nominal area of steel in tension As (mm^2/m)	20 Mpa	30 Mpa	40 Mpa
0.028	37.8	37.3	36.7	28	70.0	69.2	68.4
0.040	53.6	53.1	52.5	45	111.9	111.1	110.3
0.050	66.8	66.2	65.7	50	124.2	123.4	122.6
0.060	79.9	79.4	78.8	79	195.6	194.8	194.0
0.080	106.2	105.7	105.1	89	220.3	219.5	218.7
0.090	119.4	118.8	118.3	90	222.7	221.9	221.1
0.100	132.5	132.0	131.4	100	247.3	246.6	245.8
0.110	145.7	145.1	144.6	111	274.4	273.6	272.9
0.120	158.8	158.3	157.7	113	279.4	278.6	277.8
0.150	198.2	197.7	197.2	141	348.3	347.5	346.7
0.160	211.4	210.9	210.3	150	370.5	369.7	368.9
0.170	224.5	224.0	223.5	154	380.3	379.5	378.8
0.180	237.7	237.1	236.6	179	441.9	441.1	440.3
0.200	264.0	263.4	262.9	200	493.6	492.8	492.0

(b)

Table 2: Helix Micro-Rebar Dosage Rate

Number of Helix per unit area in tension (Helix/in^2)	Helix dosage rate, Hd (lb/yd^3)			Number of Helix per unit area in tension (Helix/m^2)	Helix dosage rate, H_d (kg/m3)		
	3000 psi	4000 psi	5000 psi		20 Mpa	30 Mpa	40 Mpa
1.18	9.0	9.0	9.0	2000	5.0	5.0	5.0
1.25	9.0	9.0	9.0	2500	5.0	5.0	5.0
1.43	9.0	9.0	9.0	3000	5.3	5.3	5.3
1.50	9.0	9.0	9.0	3500	6.2	6.2	6.2
1.53	9.0	9.0	9.0	4000	7.1	7.1	7.1
1.75	9.0	9.0	9.0	4500	8.0	8.0	8.0
2.00	9.3	9.3	9.3	5000	8.9	8.9	8.9
2.25	10.4	10.4	10.4	5500	9.8	9.8	9.8
2.50	11.6	11.6	11.6	6000	10.6	10.6	10.6
2.75	12.8	12.8	12.8	6500	11.5	11.5	11.5
3.00	13.9	13.9	13.9	7000	12.4	12.4	12.4
3.25	15.1	15.1	15.1	7500	13.3	13.3	13.3

ICF Opening Reinforcement – Rebar + Helix for Seismic Zone C - 6” Concrete Walls & Fastfooting Monolithic Pour Technology



IAPMO's Uniform Evaluation Service (UES) Evaluation Report UER-0279

- In Feb 2014, Helix Steel earned IAPMO's Uniform Evaluation Service (UES) Evaluation Report UER-0279 on Helix 5-25 Micro-Rebar.
- That report accredits Helix Micro-Rebar 5-25 and its design method under ISO Guide 65 for use as an alternative to conventional rebar and wire mesh in concrete.
- Helix Micro-Rebar 5-25 is the only discontinuous concrete reinforcement product in the world that now has a ISO certified design manual that can be followed to design vertical applications (such as walls) with Helix as the primary concrete reinforcement.

International Building & Concrete Codes

- UER-0279 opens up more than 99 countries worldwide for the immediate use and design with Helix due to the MLA/MRA agreements in place under IAF (International Accreditation Forum). It recognizes Helix 5-25 Micro-Rebar under the 2009 and 2012 revisions of the International Building Code® (IBC), International Residential Code® (IRC) and 2011 ACI 318 concrete code.
- UER-0279 documents the substantiating data provided as evidence that Helix 5-25 Micro-Rebar satisfies applicable code requirements. This allows for the specification of Helix 5-25 Micro-Rebar by architects, contractors, and designers, and approval of installations by code officials. It also provides code officials with a concise summary of the product's attributes and documentation of code compliance.

Cost-effective, Durable & Easy-to-use

- With UER-0279, building code officials have peace of mind that Helix 5-25 has been fully reviewed as an acceptable alternative to traditional reinforcement in concrete design; this accreditation is great validation for Helix, and a significant advantage for the market.
- Helix is a cost-effective, durable and easy-to-use alternative to conventional rebar and wire mesh.
- Having UER-0279 assures engineers, code officials and others that they can rely on Helix for their concrete structures.

Uniform Evaluation Service (UES)

- Products recognized under UES have successfully undergone evaluation based on applicable requirements within the International Family of Codes, as well as codes published by other entities.
- UES staff thoroughly examined Helix 5-25 Micro-Rebar product information, test reports, calculations, quality control methods and other factors to ensure the product was code compliant.

ANSI Accreditation

- The UES program is built upon IAPMO's more than 70 years of experience in evaluating products for code compliance. Accredited by the American National Standards Institute (ANSI), the program operates under ISO/IEC Guide 65, "General Requirements for Bodies Operating Product Certification Systems."
- UES technical director Brian Gerber, PE, SE, explained why Uniform Evaluation Reports are so valuable: "Helix can now reference its UER-0279 on Helix 5-25 Micro-Rebar to ensure that code officials quickly have the information, from a trusted third-party source, necessary for their quick decision on approval."

ER-279 UES Scope of Evaluation

- 1.1 Compliance To The Following Codes & Regulations:
  - 2012 and 2009 International Building Code® (IBC)
  - 2012 and 2009 International Residential Code® (IRC)
- 1.2 Evaluated in Accordance With:
  - IAPMO UES EC015-2013, adopted December 2013
  - ICC-ES AC208, approved October 2005, editorially revised November 2012
- 1.3 Properties Evaluated:
  - Shrinkage and temperature crack control in concrete
  - Structural tension and shear resistance in concrete
  - Fire Resistance

UER-0279 Helix Micro-Rebar Uses

- Helix 5-25 Micro-Rebar functions as tensile reinforcement for concrete.
- 2.1 Helix Micro-Rebar may be used to reduce shrinkage and temperature cracking of concrete. Helix Micro-Rebar may be used as an alternative to the shrinkage and temperature reinforcement specified in Section 7.12 and Chapter 22 of ACI 318 (as referenced in Section 1901.2 of the IBC and Sections R404.1.2 and R611.1 of the IRC).
- 2.2 Helix Micro-Rebar may be used as tension and shear reinforcement in other structural concrete as detailed in this report which satisfies the requirements of ACI 318 Section 1.4 and Section 104.11 of the IBC and IRC.
- 2.3 Use in Seismic Design Categories C, D, E, and F is subject to the restrictions listed in Section 5.2 of the report.

Modern Concrete

- Regular concrete is the lay term for concrete that is produced by following the mixing instructions that are commonly published on packets of cement, typically using sand or other common material as the aggregate, and often mixed in improvised containers. The ingredients in any particular mix depends on the nature of the application.
- Regular concrete can typically withstand a pressure from about 10 MPa (1450 psi) to 40 MPa (5800 psi), with lighter duty uses such as blinding concrete having a much lower MPa rating than structural concrete. Many types of pre-mixed concrete are available which include powdered cement mixed with an aggregate, needing only water.

High Strength Concrete

- **High-strength concrete** has a compressive strength greater than 40 MPa (5800 psi). High-strength concrete is made by lowering the water-cement (W/C) ratio to 0.35 or lower. Often silica fume is added to prevent the formation of free calcium hydroxide crystals in the cement matrix, which might reduce the strength at the cement-aggregate bond.
- Low W/C ratios and the use of silica fume make concrete mixes significantly less workable, which is particularly likely to be a problem in high-strength concrete applications where dense rebar cages are likely to be used. To compensate for the reduced workability, superplasticizers are commonly added to high-strength mixtures. Aggregate must be selected carefully for high-strength mixes, as weaker aggregates may not be strong enough to resist the loads imposed on the concrete and cause failure to start in the aggregate rather than in the matrix or at a void, as normally occurs in regular concrete.
- In some applications of high-strength concrete the design criterion is the elastic modulus rather than the ultimate compressive strength.

High Performance Concrete

- High-performance concrete (HPC) is a relatively new term for concrete that conforms to a set of standards above those of the most common applications, but not limited to strength. While all high-strength concrete is also high-performance, not all high-performance concrete is high-strength. Some examples of such standards currently used in relation to HPC are:
- Ease of placement
- Compaction without segregation
- Early age strength
- Long-term mechanical properties
- Permeability
- Density
- Heat of hydration
- Toughness
- Volume stability
- Long life in severe environments
- Environmental

Energetically Modified Cement

- An energetically modified cement is a cementitious material that has been produced using the EMC Activation process.
- The term "energetically modified cement" (abbreviated as "EMC" or "EMC cement") refers to a distinct class of cementitious materials.
- There are several different energetically modified cements depending on the raw materials used.

Green Cement & Ecodesign

- Although the term "energetically modified cement" implies that such compounds are cements, are more accurately be described as "cementitious materials".
- EMC can fully replace conventional Portland cement in concrete. Where raw materials other than Portland cement undergo EMC Activation, the resultant energetically modified cements are called "Alternative Cementitious Materials“ (ACM).
- Colloquially, energetically modified cements not made from large volumes of pozzolans are sometimes describes as "Green Cements", because of the significant energy and carbon dioxide savings. As such, EMC may be viewed as a contributor to the emerging field of ecodesign.

Fly Ash And Natural Pozzolans

- The usefulness of energetically modified cements depends on the performance characteristics required, based on the mechanical loads expected and the ambient environment.
- The most useful EMCs are those made from fly ash and natural pozzolans — on account of their relative abundance, the performance characteristics of the respective EMC, the relatively high Portland cement replacement ratios made available by EMC Activation using these raw materials, together with the associated energy and carbon dioxide savings.
- EMC products have been extensively tested by independent labs, including Caltrans and other concrete producers.

Development of EMC

- The term "energetically modified cement" is widely accepted in the academic community.
- The term was first used in Sweden, where the EMC Activation process was discovered in 1992 by Vladimir Ronin at Luleå University of Technology (LTU).
- The process was refined there by Dr. Ronin and others, including Lennart Elfgren (now Professor Emeritus of LTU, Division of Structural Engineering, Department of Civil, Mining and Environmental Engineering).

Origin of EMC

- The term "energetically modified cement" was used first in a paper by Ronin et al. in 1993.
- At the 45th World Exhibition of Invention, Research and Innovation, held in Brussels, Belgium, EMC Activation was awarded a Gold Medal with mention by EUREKA, the European inter-governmental (research and development) organization.
- Given that the EMC Activation process is entirely mechanical in nature (as opposed to thermal), its potential to cause significant energy savings has been further recognized independently for a number of years. This recognition continues.

Ongoing R&D of EMC

- Continuing academic work and research with energetically modified cements is ongoing at LTU, including work within the auspices of the *Sveriges Bygguniversitet* (SBU).
- The nascent "self healing" properties of EMCs have some resonance within the emerging field of biomimetics in the advanced material sciences and civil engineering disciplines. In March 2013 Elfgren presented LTU's perspective at the Future Infrastructure Forum (FIF) held at University of Cambridge.
- The research work connected with EMCs has received numerous awards from the *Elsa ō Sven Thysells stiftelse för konstruktionsteknisk forskning* (Elsa & Sven Thysell Foundation for Construction Engineering Research) of Sweden.

Effect of EMCs - Concrete Chemistry & Self-healing

- Using pozzolans in concrete provides a number of chemical pathways whereby porous (reactive) Portlandite is transformed into a number of hard and impermeable (relatively non-reactive) compounds, rather than producing the porous and soft relatively reactive calcium carbonate produced using ordinary concrete.
- Many of the end products of pozzolanic chemistry exhibit a hardness greater than 7.0 on the Mohs scale. By comparison, Tungsten is 7.5 on the scale.

Highly Reactive Pozzolans

- The greater the replacement in the concrete of Portland cement with pozzolanic cementitious materials (of which EMCs are an example), the greater the propensity for the foregoing. EMC Activation is a process which is thought to increase a pozzolan's chemical affinity for such pozzolanic reactions.
- This is yields a faster and greater strength development of the resulting concrete—at higher replacement ratios—than untreated pozzolans. As such, EMCs may be classified also as "highly reactive pozzolans". Highly reactive pozzolans are thought to yield further stabilization benefits upon the pozzolanic reaction-pathways.

Self-Healing (Natural Autogenous Property)

- It is for the foregoing reasons (and others) that it is thought pozzolanic mortars and concretes have been observed to "self-heal". This effect is considered a natural autogenous property. By virtue that EMC Activation is a process which is thought to increase a pozzolan's affinity for such pozzolanic reactions, concretes made from EMCs are no different in this regard (see major pictorial insert above).
- The same autogenous tendency been noted and studied in the various supporting structures of Hagia Sophia built for the Byzantine emperor Justinian (now, Istanbul, Turkey).
- There, in common with most Roman cements, mortars comprising high amounts of pozzolana were used — in order to give what is thought to be an increased resistance to the stress-effects caused by the various earthquakes that have disrupted the region throughout the millennia (see also, below, "Historical context of the EMC California results")

Range of EMC Concretes Produced

- The performance of concretes made from energetically modified cements can be custom-designed. Hence, concretes can range from those exhibiting superior strength and durability that reduce the carbon footprint at up to ~70% as compared to concretes made from Portland cement, through to the production of rapid and ultra-rapid hardening, high-strength concretes (for example, over 70 MPa / 10,150 psi in 24 hours and over 200 MPa / 29,000 psi in 28 days). This allows energetically modified cements to yield High Performance Concretes

Pozzolanic Characteristics

- Generally, the strength and strength-development of pozzolan concretes depend upon the "pozzolanic" characteristics of the raw material that is employed to make it.
- For example, fly ash in its natural state is typically more "pozzolanic" than volcanic ash — although care should be taken not to necessarily imply that all fly ashes are per se more "pozzolanic" than all volcanic ashes.
- In a similar vein, the nascent characteristics of the raw material undergoing EMC Activation may also act as a consideration as to the upper limit of Portland cement replacement by an energetically modified cement.

Strength Development

- Moreover, in practical "everyday" terms, the key consideration is a concrete's strength-development within a specified time period. In a project environment, this means a concrete will need to develop a strength within a given time period that either matches or exceeds a project's specifications.
- Currently, the replacement-ratio of an EMC made from fly ash may exceed 70%. Some EMC mix designs can entirely replace Portland cement.

Noxious Emissions & Leachability Tests

- The EMC activation of fly ash is entirely mechanical in nature and does not involve any heating or burning in the process.
- Leachability tests were performed by LTU in 2001 in Sweden on behalf of a Swedish power production company.
- These tests confirmed that EMC made from fly ash "showed a low surface specific leachability" with respect to "all environmentally relevant metals."

EMC Projects & Performance

- Energetically modified cements have been used in large infrastructure projects in the United States. When EMC is made from fly ash, high Portland cement replacements (i.e., the replacement of at least 50% Portland cement) yield concretes consistent field results in high-volume applications. This is also the case for EMC made from natural pozzolans (e.g., volcanic ash).
- For example, volcanic ash deposits from Southern California were independently tested. At 50% Portland cement replacement, the resulting concretes exceeded requirements:
- At 28 days, the compressive strength was 4,180 psi / 28.8 MPa (N/mm^2).
- The 56-day strength exceeded the requirements for 4,500 psi (31.1 MPa) concrete, even taking into account the safety margin as recommended by the American Concrete Institute.

EMC Activation

- EMC Activation "has a sufficient positive impact on the water requirement to obtain satisfactory workability and strength of concrete, at about 50% replacement of Portland cement."
- the "index of pozzolanic activity at 7 days was 80% and at 28 days was 88%, which exceeded the relevant standard's requirements (75% at both ages)."
- The particle-size distribution and morphology of the EMC produced were studied by Luleå University of Technology. Those studies "evidenced the improvement in the surface smoothness of particles of natural pozzolans processed by the proprietary EMC method."

Portland Cement & EMC Activation

- Treating Portland cement with EMC Activation will yield High Performance Concretes.
- These HPCs will be high strength, highly durable, and exhibiting greater strength-development in contrast to HPCs made from untreated Portland cement, which can have moderate to challenging durability impairments by comparison.

Durability Tests

- For example, durability tests were been performed according to the "Bache method" (see diagram). The Bache method induces the sequence of saturation by salt water of 7.5% sodium chloride (i.e., a brine, which by definition is of greater salt concentration than sea waters), followed by freezing or heating in a 24-hour cycle, in order to simulate high diurnal temperature ranges.
- Concrete made from ordinary Portland cement without additives, has a relatively impaired resistance to salt waters. Hence, the Bache method is generally accepted as one of the most severe testing procedures for concrete.

EMC High Performance Concrete

- Samples made of high performance concrete comprising (a) EMC (comprising Portland cement and silica fume both having undergone EMC Activation) and (b) Portland cement, having respective compressive strengths of 180.3 and 128.4 MPa (26,150 and 18,622 psi) after 28 days of curing, were then tested using the Bache method.
- The resulting mass-loss was plotted in order to determine durability. The test results showed:
  - EMC high performance concrete showed a "consistent high-level durability" throughout the entire testing-period. For example, "practically no scaling of the concrete was observed", even after 80 Bache method cycles.
  - Whereas, the reference Portland cement concrete had undergone "total destruction after about 16 Bache method cycles, in line with Bache's own observations for high-strength concrete."

50% Increase In Strength

- In other words, treating Portland cement with the EMC Activation process, may increase the strength-development by nearly 50% and also significantly improve the durability, as measured according to generally-accepted methods.
- All energetically modified cements also exhibit high resistances to chloride and sulfate ion attack, together with low Alkali-Silica Reactivities (ASR). These features allow concretes made from energetically modified cements to exhibit superior durabilities as compared to concretes made from Portland cement, a feature common to all concretes comprising pozzolans.
- An early project using EMC made from fly ash was the construction of a road bridge in Karungi, Sweden, with Swedish construction firm Skanska. The Karungi road bridge has successfully withstood the tests of time, despite Karungi's harsh subarctic climate and extremely divergent annual and diurnal temperature ranges.

Adding Value via EMC-ECC Concrete

- Through local purchasing of quality fly ash from coal power plants in Bridger, WY or Boardman, OR, bulk transport via railroad unit trains could allow for substantially lowering costs for production of EMC in surrounding communities including Idaho.
- Partnerships with local ready-mix producers would allow for using existing infrastructure for production of low w/cm ratio, superplasticizers, self-consolidating, high strength, high performance concrete with micro-rebar, providing early strength and durability while substantially reducing material and labor costs for ECC.

Energy Efficiency & Savings

- Insulated concrete forms (ICF), geothermal heat pump systems, energy recovery ventilators (ERV), state-of-the-art passive windows and doors, energy efficient appliances, LED light bulbs, and energy efficient electronics (LED TVs), will be used to reduce energy loads.
- For grid-connected Zero-Net Energy (ZNE) homes that produce solar power, it may be strategically advantageous to use all electric appliances in place of natural gas.
- In some cases, this may warrant investment in a battery storage system in conjunction with solar PV, wind power, and sterling engines that are fueled by woody biomass.

Increasing Energy Efficiency, Quality & Affordability

- Extremely tight, super-insulated concrete homes can be constructed in a fraction of the time that it takes to build stick-frame structures.
- It is estimated that experienced crews can install timber framework (in place of shoring) and pine decking, Quad-Deck ICF, and decorative concrete floors for about $10/sf.
- Geothermal heat pump systems and field loops can be installed around the structure footings during excavation of the basement, reducing installation costs by as much as 40-50%.

Specialized ICF Crews

- For experienced ICF crews, passive windows and doors, HVAC, electrical and plumbing systems, and exterior insulated cultured stone, can be installed almost simultaneously.
- Similarly, timber frameworks, ceiling pine/fir decking, softwood flooring, custom pine cabinets , decorative concrete countertops, and finish carpentry can be installed faster with a higher level of quality via specialized ICF crews.

Affordability

- Through a 90-95% decrease in energy loads, the use of solar thermal integrated with geothermal heat pump and ERV technologies (which increases total energy efficiency by up to 900% in comparison with conventional natural gas HVAC systems), capitalizing on the thermal mass of concrete, decreasing labor costs via innovative ICF technology, experienced ICF crews, and using locally available products, unprecedented quality and affordability is provided for construction of energy efficient green homes.

Homeowner Sweat Equity

- Additionally, homeowners can do much of the exterior cultured stone products, drywall, and painting, thus adding value via sweat equity.
- This allows the homeowner to purchase more home, invest in a solar PV power system for achieving a ZNE Home, or reduce their mortgage payment.

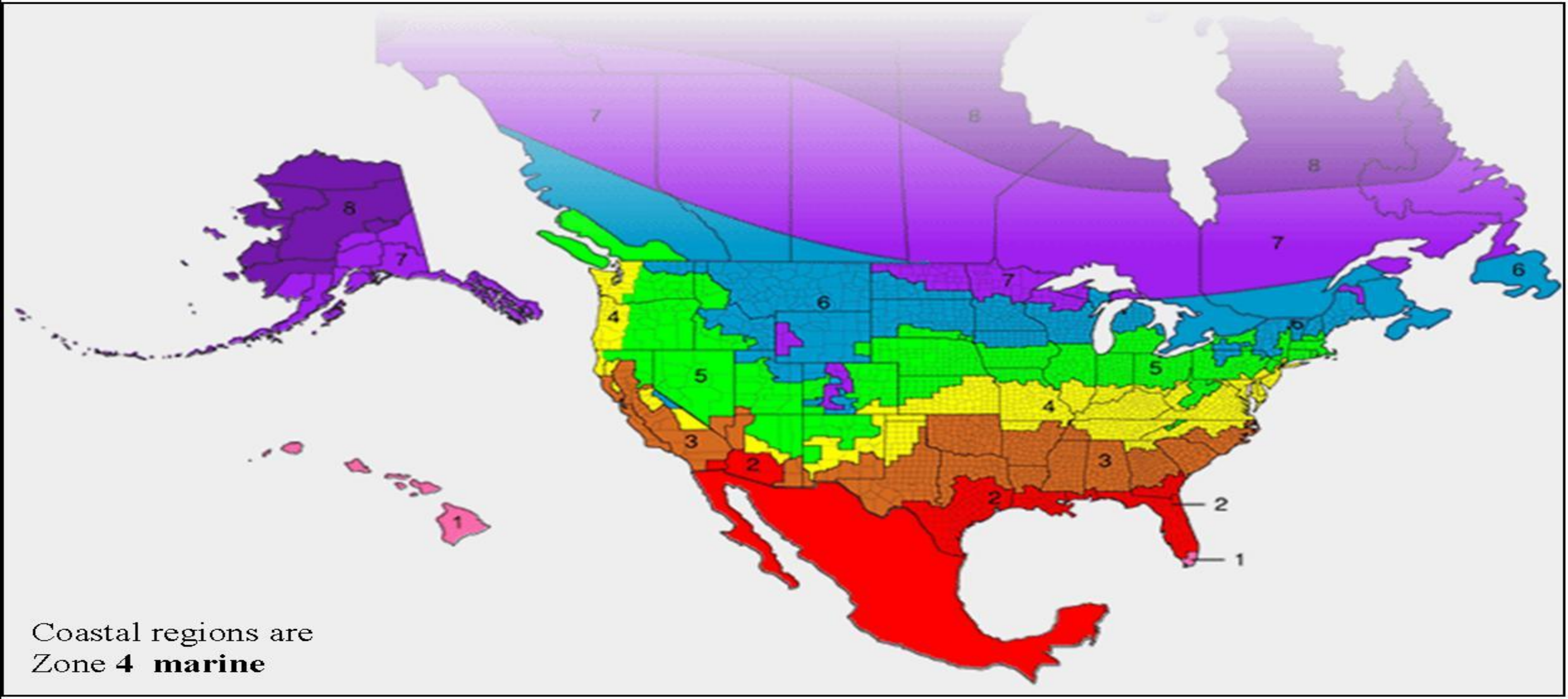
Energy Tax Credits & EEM

- Federal & state tax credits (30% for geothermal heat pump and solar power systems including radiant heating, cooling and hot water; and energy recovery ventilators); and Energy Efficiency Mortgages (EEM) will provide further economic advantages that, in most cases when combined with reducing labor and material costs, will more than offset the 10-20% increase in typical construction costs for ZNE homes.

International Energy Conservation Codes Commission (IECC)

- Summary of Changes to IECC 2012 (~30% better than IECC 2006)
- Major changes
  - Consolidated with IRC energy chapter (actually a change to the IRC, not the IECC)
  - Mandatory whole-house pressure test
  - More stringent duct leakage test
  - DHW distribution system requirements
- Key non-changes
  - Retains prohibition on envelope-equip. trade-offs
  - Makes lighting requirements "mandatory"
- (http://www.resnet.us/uploads/documents/conference/2012/pdfs/Barcik-Energy_Code-IECC2012_vs_2009IECC.pdf)

ASHRAE/IECC Zone Map



IECC 2012 Insulation Requirements

Cold-climate Buildings

- **Mandatory Foam Sheathing or ICF**
  - The 2012 International Energy Conservation codes will require new homes in cold climates to have exterior foam sheathing, or some similar layer of continuous insulation that interrupts thermal bridging due to using wood studs.
  - An alternative to stick-frame construction is Insulated Concrete Forms (ICF) which meet or exceed all 2012 IECC insulation and tighter envelope requirements.

Summary of IECC 2012

- The 2012 International Energy Conservation Code requires more insulation, a tighter envelope, tighter ducts, better windows, and more efficient lighting than the 2009 code.
- The PHMH project is designed to meet or exceed all of these building requirements through industry partnerships with leading technology providers who will be showcasing their technologies and products at the PHMH.

Immediate Energy Savings

- New 2,400 square foot single family homes in Idaho that meet the 2012 IECC will cost an additional $1,350-1,892 in construction costs per new home.
- Energy cost savings are estimated at between $207 and $267 per year. Stated differently, a homeowner’s monthly utility bill savings are at least triple the additional mortgage payment needed to cover the cost of the energy saving features required by the 2012 code.

Zero-Net Energy (ZNE) Homes

- Idaho residents buying new single family homes meeting the 2012 IECC will pocket between $4,139 to $5,038 in net savings over the life of their 30 year mortgage according to an analysis of energy savings and incremental construction costs by the Building Codes Assistance Project and ICF International.
- Similarly, the PHMH project is designed to provide an immediate cash flow from day 1, increasing savings by reducing energy loads by 90% and allowing homeowners to build ZNE Homes with minimal investments in grid-connected solar photovoltaic (PV) power systems.

Industry Partners

- Professional Services
- Manufacturers
  - Core manufacturers, e.g., ICF, Solar Thermal Collectors, ERV/Ground Source Heat Pumps, radiant heating, cooling, and hot water; HP windows and doors; concrete providers; timber providers
  - Other manufacturers, e.g., supporting products such as
- Contractors

Professional Services

- James Stewart, Architect, Montana State University, Integrated Design Lab
- Gunnar R. Gladics, Research Scientist – Architectural Energy Specialist, University of Idaho, College of Architecture, Integrated Design Lab – Boise

Core Product Manufacturers

- NUDURA Insulated Concrete Forms & Wall Building Innovations using Hybrid Block-Panel Technology
- Quad-Deck Insulating Concrete Forms & Floor/Vaulted Ceiling Panel Building Systems
- InsulStone - Concrete Cultured Stone and Stucco with R-6 EPS Insulation
- Envision Building Innovations & Alpen High Performance Windows
- Renewable Energy Northwest Thermal Solar Hot Water & Radiant Floors
- UltimateAir® RecoupAerator®/Hybrid GSHP
- Energized Glass, LLC

Pending Core Product Manufacturers

- Hammer & Hand Passive Entry Doors
- Concrete companies (to be determined)
- Lodge Logs (Boise, ID)
- Western Timber Products, Inc.
- High Efficiency Appliances (to be determined)
- Solar (photovoltaic) Power Systems (to be determined)

Other Pending Product Manufacturers

- Düraamen decorative concrete and resinous flooring systems
- Powerwise Systems, InView Passive House and eMonitoring hardware and software
- Control4 Home Automation Solutions & Home Security

Contractors & Developers

- Ben & Don Poulsen, General Contractors
- Scott Flynn - Flynner Homes – Energy Efficient Construction – General Contractor
- Jason Fuller, PE, Idaho Geothermal, HVAC, geothermal heat pumps, ERVs, and Solar PV systems

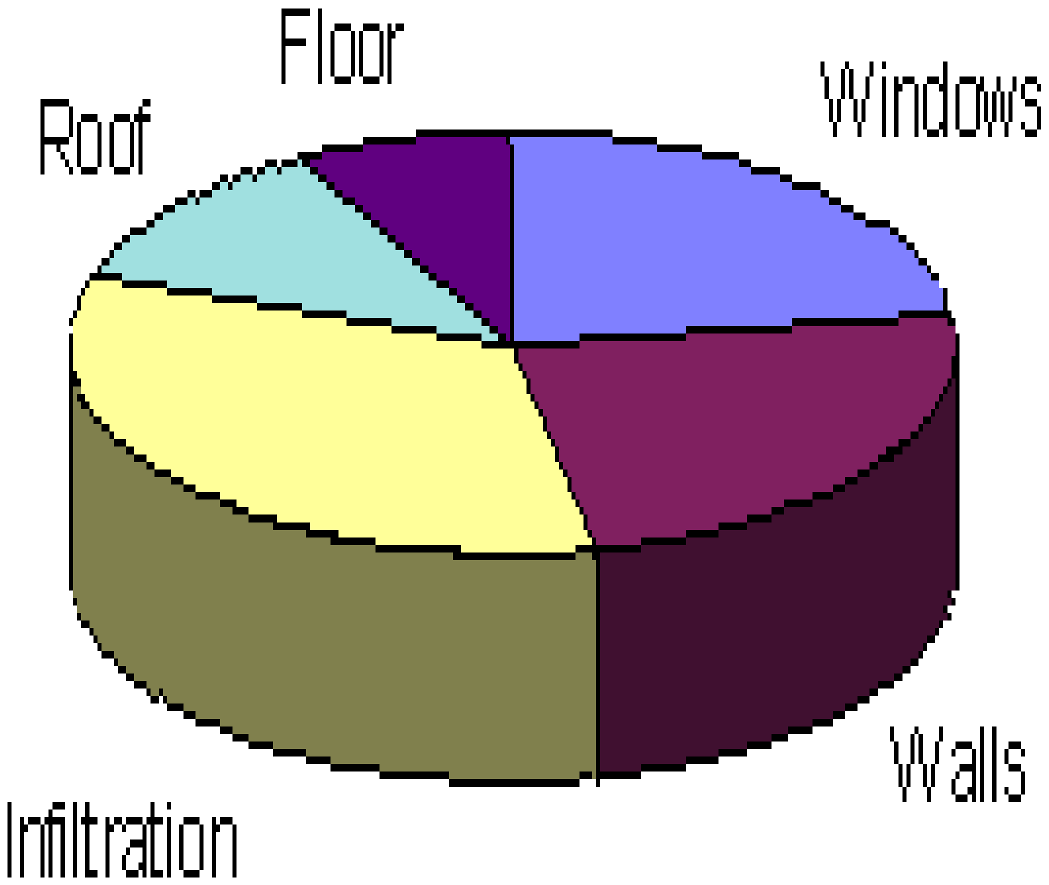
ICF vs. Wood Frame Structures

- According to an independent study/comparison referred to by the Portland Cement Association, analyses show that energy for heating and cooling account for 20-72% of total annual energy costs, depending on the location of the structure.
- Due to the thermal mass of the concrete walls, houses with concrete walls have lower heating and cooling costs than houses with conventional frame walls, except for locations where the concrete walls were extremely under-insulated.

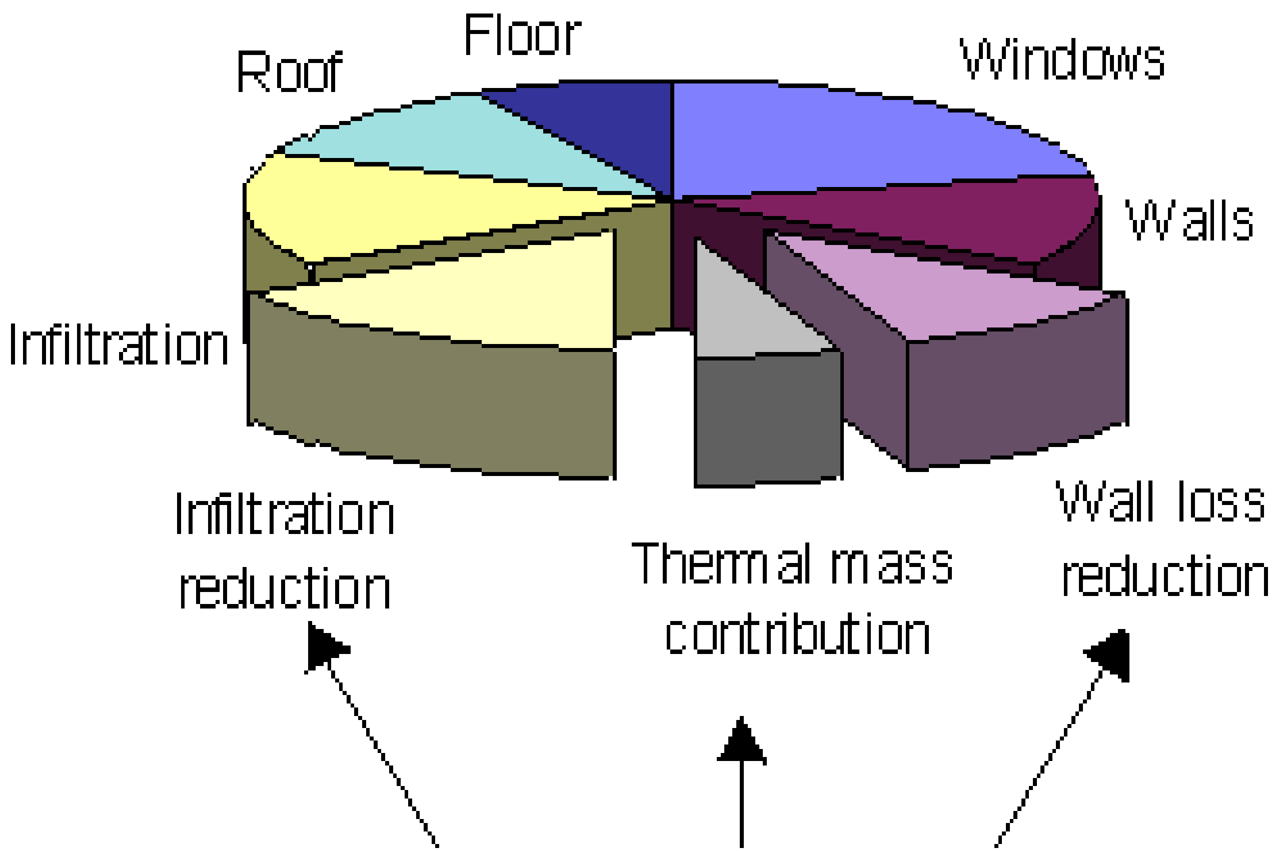
Reducing Energy Losses via ICF

- ICF construction can reduce energy losses resulting from stick-frame construction by up to 80%:
  - Up to 35% reduction due to decreasing infiltration/convection via concrete
  - Up to 35% reduction due to reducing conduction in envelope (continuous EPS foam insulated concrete walls, floors and ceiling)
  - Up to 10% reduction due to increasing thermal mass via concrete floors in conjunction with passive solar radiation

Stick-Frame Energy Losses



ICF Energy Loss Reductions



Over 80% Total Energy Reduction by adding ICF Radiant Floors & ICF Vaulted Ceiling Structures

R-9 to R-12 Passive Windows for ICF Structures

- Internal ICF bucks, EPS foam framing, 4-5 pane glazing, state-of-the-art foam-filled fiberglass hybrid frame with foam thermal break and wood/wood polymer finish will provide unprecedented thermal resistance for windows and doors.
- Strategic window placement and glass treatments coupled with strategic eaves and shades for capitalizing on passive solar radiation and thermal mass of concrete can reduce energy loss by another 10-20% for ICF structures.

Insulated Concrete Forms

- ICF technology integrates concrete with foam insulation, providing up to R-50 thermal heat efficiency in walls at a cost similar to conventional 2x6 wood frame and fiberglass (batting) insulation construction, but with the following advantages:
  - Energy savings up to 80% through tighter envelope
  - Increasing thermal mass via ICF, masonry or concrete exterior, concrete floors, optimizing solar radiation during cool seasons, and minimizing solar radiation during warm seasons (passive solar house)
  - Relatively short time of installation
  - Ease of maintenance and longevity (mold proof EPS foam and concrete)
  - Soundproofing
  - Earthquake and hurricane/tornado proof construction

ICF Construction Benefits

Short Term Benefits

- Reduce required cooling tonnage by over 90% for strategic passive cooling
- Shorten construction time
- Fit any design with ease
- Reduce worker injuries with lightweight materials
- Lower labor costs with smaller crews

Long-Term Benefits

- Lower maintenance and lifetime operating costs with higher energy efficiency
- Profit from cleaner, quieter and more comfortable interiors
- Increase longevity and structural integrity
- Enhance security with greater fire resistance and storm safety

Energy Performance & R-Values of Insulated Concrete Forms

- Fact or Fiction: "The R-value tells me how much energy my house will use, right?"
- R-value measures the resistance a material has to heat transfer (conductance), this much is true. R-value alone, however, does not fully describe the energy performance of a building.
- Everyone in the ICF community knows that ICF buildings far outperform framed buildings with comparable stated R-values in terms of energy efficiency and comfort level, but why is that?

Energy Performance Factors

- The main factors affecting actual energy performance of a building are:
  - Thermal Conduction
  - Thermal Convection
  - Thermal Radiation
  - Thermal Mass
- Each of these energy factors must be considered when planning and building an energy efficient structure.

Thermal Conduction

- Thermal conduction is the heat transfer through a material by contact of one molecule to the next. This is the only factor an R-value measures.
- However, as indicated above, thermal conduction is not the only mode of energy loss in a building.
- In fact, conduction contributes less to energy losses in wood frame buildings than convection which is not measured by R-values.

Wood Framing & Thermal Conduction

- We have all heard builders claim to build "R-13" or "R-21" walls with wood frame construction.
- The problem with those claims is that only the highest rated component in the walls - the insulation itself - performs at these stated R-values.
- A wood frame wall is made up of several components, not all of which have the same R-value. For instance, a 2x4 or 2x6 stud has an R-value of only about R-5 or R-7.

Wood Framing & Thermal Conduction Cont.

- Every 16 inches or so, one of these components breaks the insulation layer and forms a 'thermal bridge', conducting heat through the walls at high rates. Adding up the area of studs, plates, and headers, *12-16% of the total wall area is an R-5 or R-7 thermal bridge*, all detracting from the stated R-value.
- In addition, batt insulation tends to sag over time and leave spaces without any insulation! How can those builders claim only the highest component R-value? From a 'whole-wall' perspective, framed walls operate at far lower R-values.

ICF & Thermal Conduction

- Most ICF walls consist of two layers of EPS, with a center cavity to contain concrete.
- The EPS remains in place after pouring concrete to provide two largely *uninterrupted layers of insulation* rated at roughly R-20 or higher.
- From a 'whole-wall' perspective, an ICF wall actually lives up to the stated R-values because thermal bridging is minimal.

ICF Technology Advantages

- Ultra Energy-Efficient because of continuous EPS insulation (higher & uniform R-value), greatly reduced air infiltration, and the thermal mass effect of concrete.
- Much more Comfortable and Healthy because of even inside temperatures (no cold spots or nasty drafts), far better sound attenuation, and low risk of mold growth and allergen infiltration.
- Longer-lasting and more resistant to natural disasters, rot, mold, and pests because the solid reinforced concrete is up to 8 times stronger and nearly impenetrable (even for car crashes) - it's what gives bunkers their strength!

Thermal Convection

- Thermal convection is heat transfer by movement of currents within fluids (or gases).
- When considering energy performance of buildings, it's the air moving between the inside and outside or 'air infiltration'.
- A common measurement is 'Air Changes per Hour' at a blower-door induced pressure differential of 50 Pascal (ACH50).
- US Energy Star standards for new homes require less than 4-7 ACH50.
- By comparison, British standards are 3-5 ACH50, Canadian R-2000 standards are 1.5 ACH50, and Swedish standards are 0.5 ACH50 or less.

Wood Framing & Thermal Convection

- In wood frame buildings convection can be felt as ‘drafts’. It is usually the biggest source of energy loss in a structure.
- Air infiltration accounts for *up to 40% of the energy losses* of a wood-framed structure.
- Heat is carried by *air leaking through thousands of cracks*, openings, and joints between all the pieces of the building shell.

Wood Framing & Thermal Convection cont.

- Major culprits include framing connections, wall, floor & roof intersections, shrinkage of wood and caulking, and poor installation of components and sealants.
- A typical new wood frame home has between 1.75 and 3 air changes per hour (ACH50). As the wood shrinks and sealants deteriorate, the ACH50 drops to <u>*between 5 and 10 ACH50*</u> in subsequent years.
- Old wood frame homes commonly have 10 to 20 ACH50.

ICF Thermal Convection

- ICF walls & roofs are an effective air barrier because the concrete is poured in semi-liquid form, forcing air out of the cavity and filling every void after consolidation.
- A chemical reaction turns the concrete into *a solid without passages for air to leak*, thus eliminating a major percentage of air infiltration.
- ICF homes consistently perform at *0.5 to 2.5 ACH50 and less*, largely depending on the installed roof type and proper sealing of the structure/envelope.

ICF Thermal Convection cont.

- Most air infiltration in an ICF home is through a conventional roof and around windows & doors.
- Using ICF such as Quad-Deck for the roof (which converts wasted attic space into value added living space) can allow for achieving <0.5 ACH50 in conjunction with proper installation, sealing, and insulation of passive windows and doors.
- Energy or heat-recovery ventilators (ERV or HRV) will be used to eliminate exterior exhaust vents, providing further energy savings and allowing adequate air exchange in extremely airtight buildings.

Thermal Radiation

- Thermal radiation transfers heat via electromagnetic waves, which for buildings are mostly the sun’s rays.
- Depending on factors like site & location of the building and the prevailing climate, Passive Solar Building Design helps optimize a building's absorption and reflection of solar radiation through strategic solar orientation, placement of windows and shading elements, choice of finishes, and incorporation of thermal mass.

Thermal Mass

- Thermal mass refers to a material's capacity to store heat, e.g., heat capacity. Concrete, cultured stone, and (adobe) bricks have high thermal mass, which can act like a battery for storing thermal energy.
- The classical use of thermal mass is in desert climates (including Boise, ID), where outside temperatures swing above inside temperatures during the day and below at night.

Thermal Mass cont.

- High mass building shells can store the heat from the outside during the day and release that heat to the inside at night - keeping the inside comfortable (using almost no additional energy).
- In temperate climates, thermal mass is best used in combination with the principles of passive solar design, e.g., allowing the sun to heat high thermal mass (concrete) floors and connected structures through strategically placed windows during cool seasons.

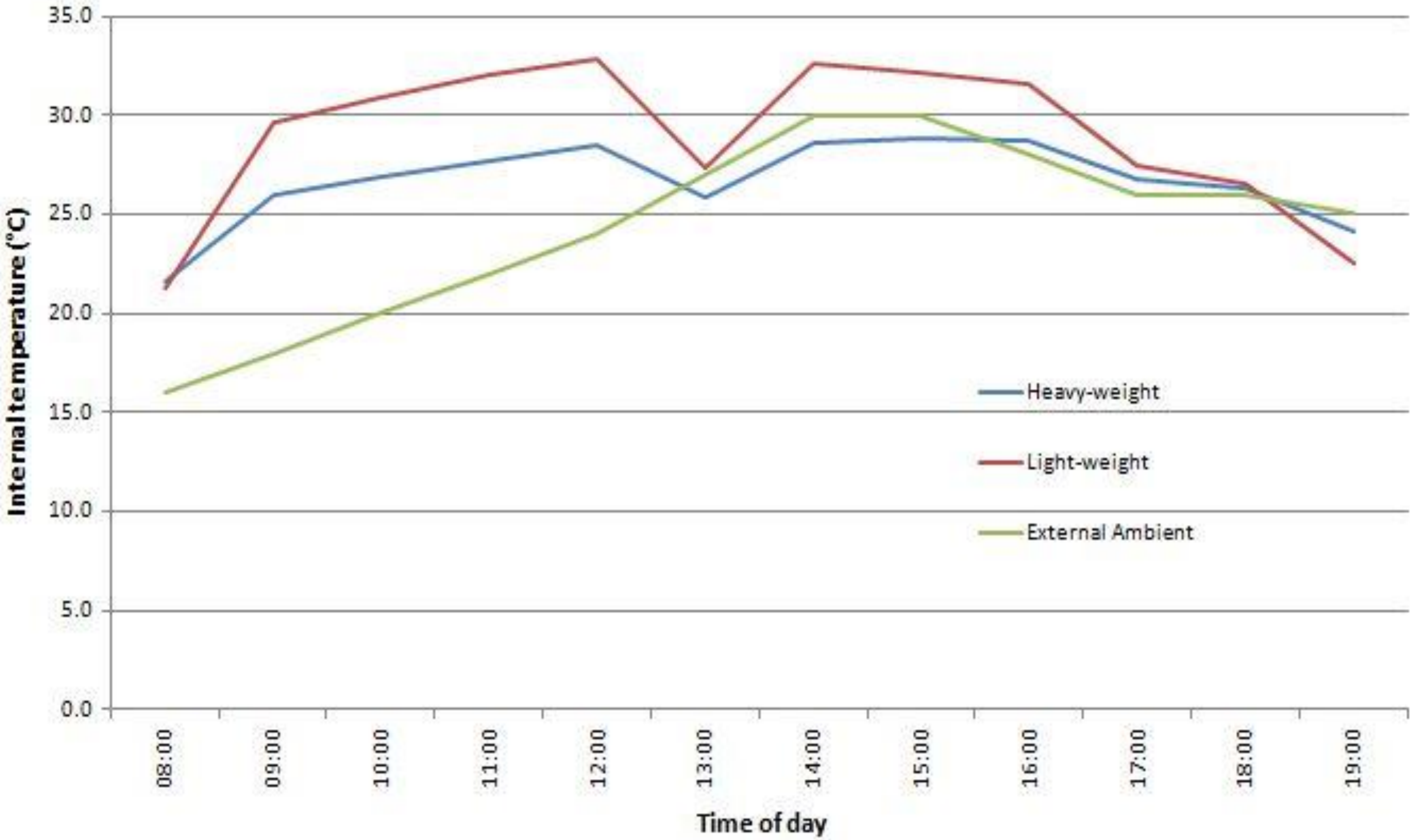
Thermal Mass & Building Design

- **Thermal mass** is a concept in building design that describes how the mass of the building provides "inertia" against temperature fluctuations, sometimes known as the **thermal flywheel effect**.
- For example, when outside temperatures are fluctuating throughout the day, a large thermal mass within the insulated portion of a house can serve to "flatten out" the daily temperature fluctuations, since the thermal mass will absorb thermal energy when the surroundings are higher in temperature than the mass, and give thermal energy back when the surroundings are cooler, without reaching thermal equilibrium.

Thermal Mass

- Is distinct from a material's insulative value, which reduces a building's thermal conductivity, allowing it to be heated or cooled relatively separate from the outside, or even just retain the occupants' thermal energy longer.
- Scientifically, thermal mass is equivalent to **thermal capacitance** or **heat capacity**, the ability of a body to store thermal energy.

Effect of Heavy-weight and Light-weight constructions on the internal temperature of a naturally ventilated school classroom



Understanding the Properties of Thermal Mass

- Though thermal mass has always been an aspect of buildings, only in recent years has it evolved as a tool to be deployed in the conservation of energy.
- Understanding the properties of thermal mass and its use, particularly in context, is critical to realizing both benefits and potential pitfalls.
- This understanding begins with the concept of thermal admittance.

Thermal Admittance

- Thermal admittance (aka heat transfer coefficient) quantifies a material's ability to absorb and release heat from a space as the indoor temperature changes through a period of time.
- Admittance values can be a useful tool in the early stages of designing a building or structure when assessing heat flows into and out of thermal storage.

Thermal Admittance Calculation

Thermal Admittance is measured in $W/(m^2K)$. So that

$$\mathbf{h = \Delta Q / A \times \Delta T}$$

h = heat transfer coefficient, $W/(m^2K)$
ΔQ = heat input or heat lost, W
A = heat transfer surface, m^2
ΔT = difference in temperature between the solid surface and the adjacent air space.

Thermal Admittance Values

- Higher admittance values indicate higher thermal mass.
- Thermal admittance is fully described in EN ISO 13786:2007.
- The framework described also provides the basis for the CIBSE 'Simple Dynamic Model' for calculating cooling loads and summertime space temperatures (CIBSE (2005) Guide A: Environmental design).

Admittance Values for Typical External Wall Elements (based on a 24 hr. cycle)

External wall	Internal finish	Admittance value
Timber frame (brick outer leaf)	Plasterboard	1.0
	Wet plaster	
Masonry cavity wall (100mm aircrete block)	Plasterboard	1.85
	Wet plaster	2.65
Masonry cavity wall (100mm dense aggregate block)	Plasterboard	2.65
	Wet plaster	5.04

Source: The Concrete Centre (calculated according to EN ISO 13786:2007)

Factors that Determine Thermal Mass

- Specific Heat Capacity
- Density
- Thermal Conductivity

Specific Heat Capacity

- Specific heat capacity refers to a physical material's capacity to store heat for every kilogram of mass contained in that material.
- A material of 'high' thermal mass has a high specific heat capacity.
- Specific heat capacity is measured in J/kg.K

Density

- The density refers to the mass (or 'weight') per unit volume of a material and is measured in kg/m^3.
- A high density material maximizes the overall weight and is a characteristic aspect of 'high' thermal mass.

Thermal Conductivity

- Thermal conductivity measures the ease with which heat can travel through a material.
- For 'high' thermal mass, thermal conductivity usually needs to be moderate so that the absorption and release of heat synchronizes with the building's heating and cooling cycle.
- Thermal conductivity is measured in units of W/m·K

Effectiveness of Thermal Mass for Common Building Materials

Material	Specific heat capacity (J/kg K)	Thermal conductivity [W / (m · K)]	Density (J/kg K)	Effectiveness
water	4200	0.60	1000	high
stone	1000	1.8	2300	high
brick	800	0.73	1700	high
concrete	1000	1.13	2000	high
unfired clay bricks	1000	0.21	700	high
dense concrete block	1000	1.63	2300	high
gypsum plaster	1000	0.5	1300	high

SAP & Thermal Mass

- SAP 2009 uses thermal mass in calculating the heating and cooling load of a building.
- SAP uses the kappa (k) value to determine thermal mass. 'k' is the measure of the heat capacity per unit area in kJ/m^2K of the 'thermally active' part of the construction element:

  $$\mathbf{k = 10^{-6}\, \Sigma_i\, p_i\, c_i\, d_i}$$

p_i = the density of the layer 'i' in the construction (kg/m^3)
c_i = the specific heat capacity of the layer 'i' (J/kg K)
d_i = the thickness of the layer 'i' (mm)

Kappa Value Equation

- The calculation is performed over all the layers of the construction element, starting at the inside surface and stopping at whichever of these conditions occurs first (including its occurrence part-way through a layer):
  - half way through the construction
  - an insulating layer
  - a maximum thickness of 100mm

Thermal Mass Parameter

The kappa value is used in the calculation of the Thermal Mass Parameter (TMP):

TMP = Cm / TFA

Cm = sum of (area x heat capacity) construction elements
TFA = total floor area

The 'k' value is a relatively crude way of determining thermal mass. It makes assumptions about the extent of the thermally active volumes of a material and ignores the effect of thermal conductivity in calculating the period over which heat is absorbed and emitted from the material.

ISO 13786 provides a more effective method of determining thermal mass for materials including wall, floor and ceiling construction.

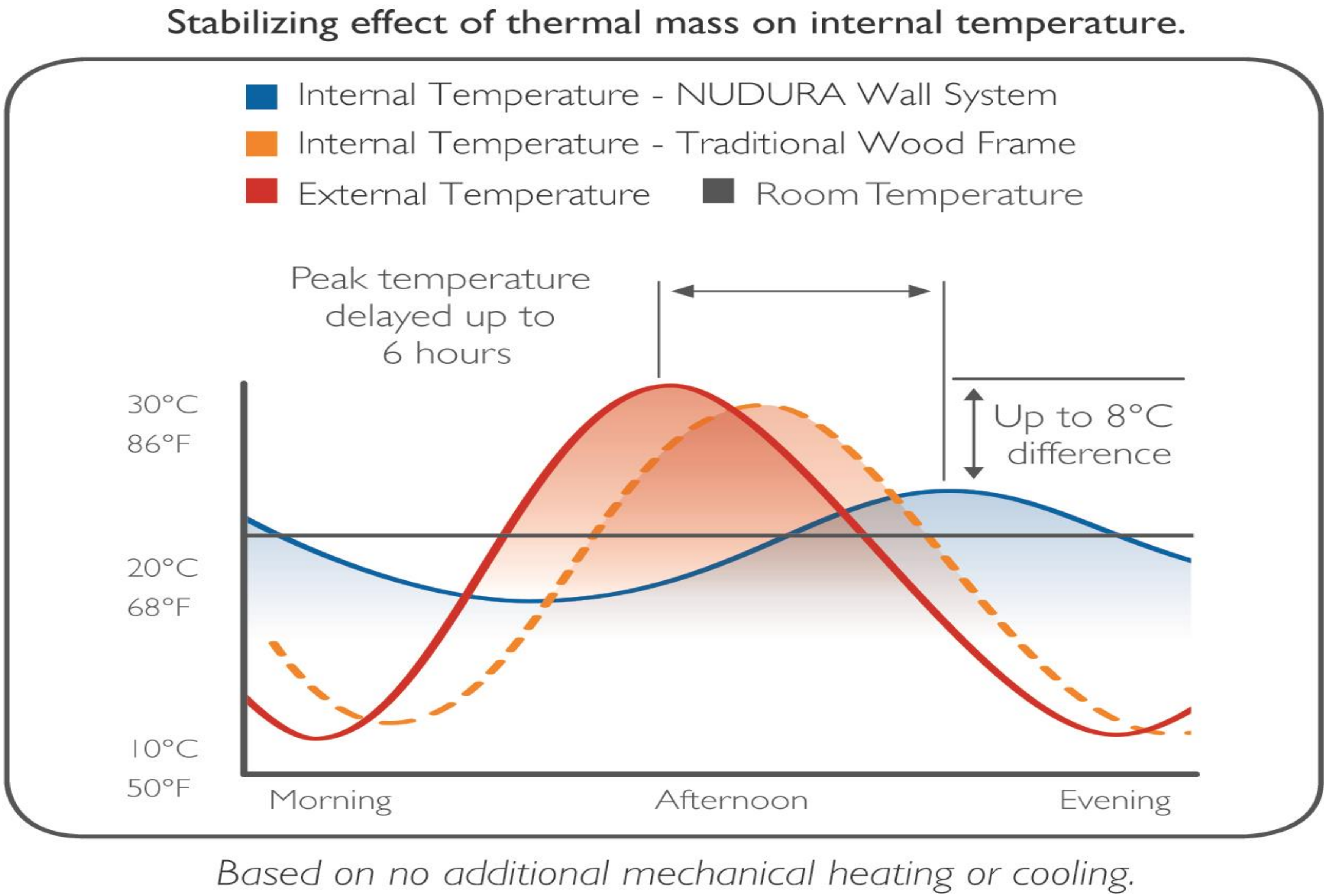
How Thermal Mass Works

- By alternately storing and releasing heat, high thermal mass 'smooths out' the extremes in daytime temperatures.
- In warm/hot climates where there is significant temperature variation between day and night ('diurnal' variation), heat is absorbed during the day and then released in the evening when the excess can be either 'flushed out' through natural ventilation or it can be used to heat the space as the outside temperature drops.
- The entire process can then be repeated the next day.

Thermal Mass of Concrete vs. Wood

- Wood frame buildings have almost *no thermal mass* - unless the exterior walls are finished with concrete products, brick or other masonry product.
- In contrast, concrete has a relatively high ability to store and release thermal energy.
- This makes concrete an ideal building material for use in passive house design, particularly for passive solar radiation.

ICF Exterior Wall System



ICF Parameters

- Though the above illustration is based on a specific product for a particular ICF manufacturer, similar though varied results would be obtained from different products with lower or higher thermal mass (volume of concrete used in walls, floors/ceiling and roof structures, etc.).
- For an all ICF structure the volume of thermal mass and ability to stabilize thermal temperature within that structure would be dramatically enhanced.

High Heat Capacity & Moderate Conductivity

- ICF exterior structure walls and connected floors have a high storage capacity with moderate thermal conductivity. Thus, it provides the most useful level of thermal mass sandwiched between EPS foam layers.
- This helps to stabilize the internal temperature from day to night temperature fluctuations.
- Increasing thermal mass by constructing interior walls, floors, ceilings and roofs with ICF and concrete slabs could substantially increase energy conservation.

Capitalizing on Concrete’s Thermal Mass

- Concrete walls conserve heat or cooling, acting as an energy sink. According to the Portland Cement Association this contributes/comprises about 6% of the needed energy for a structure.
- Based on thermal mass, when floors, interior walls, and roof structure are also constructed of ICF, solar thermal, passive solar radiation, and the concrete structure can combine to contribute over 24% of the needed energy of the structure.
- Concrete floors, concrete countertops, strategic concrete eaves, solar thermal radiant floors, and passive solar window/glazing design could potentially provide over 40% of the volume of energy required for the PHMH.

ICF Thermal Mass

- High mass construction built into ICF walls & floors can significantly reduce the requirements for active heating and cooling systems in many climates.
- This translates into *on-going energy savings from using smaller sized HVAC equipment*.
- Most current residential HVAC sizing software programs do not factor in the effects of thermal mass.

Concrete's Thermal Mass

- Concrete's "thermal mass" provides the ability to smooth out large temperature swings.
- It keeps the walls warmer when the outdoor temperature reaches its coldest extreme and cooler when the outdoor temperature is hottest.

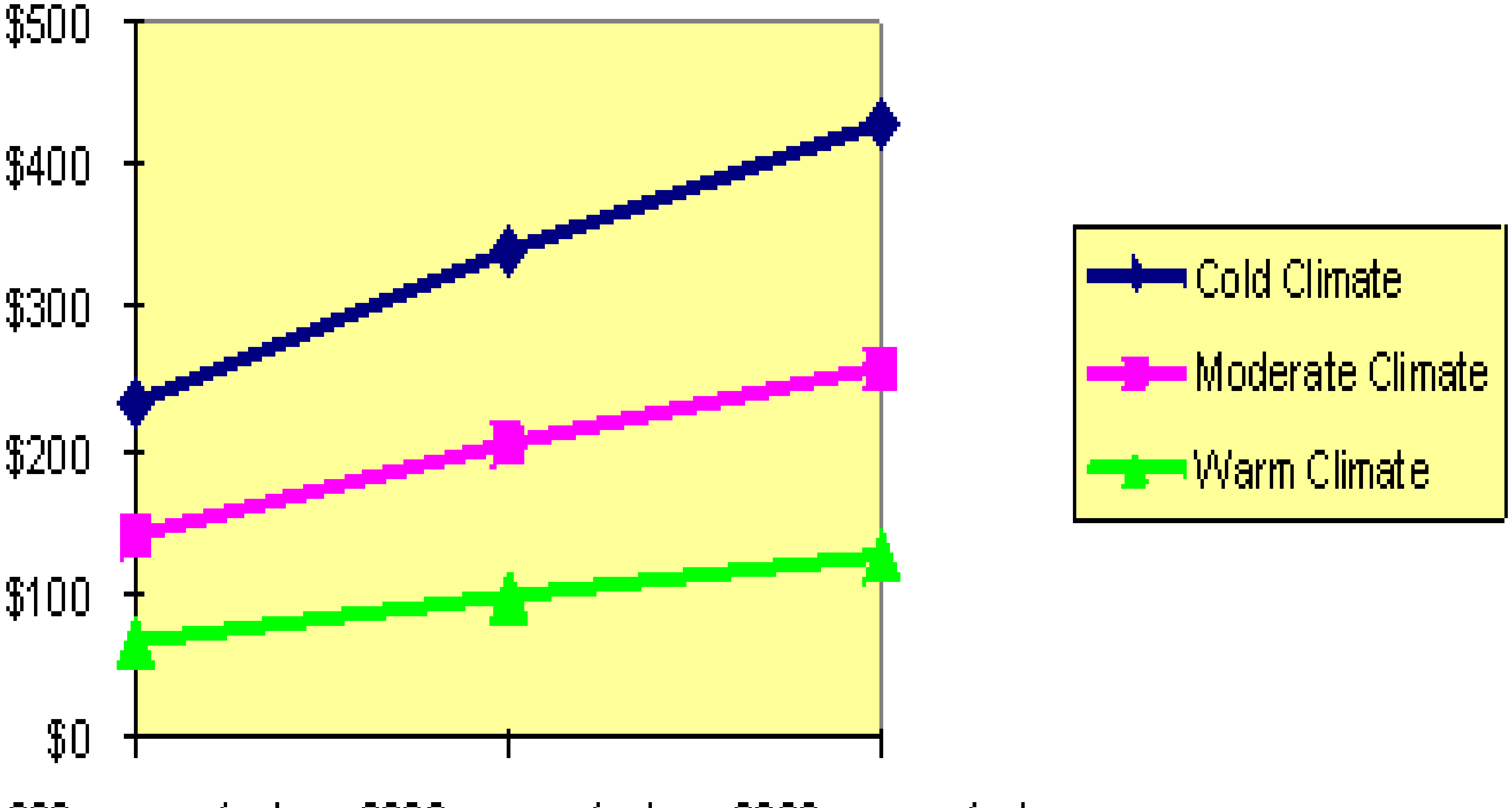
Concrete Homes Save Energy

- According to the Portland Cement Association, building a concrete home with ICFs saves energy and money.
- The greater insulation, tighter construction and temperature-moderating mass of the walls conserve heating and cooling energy much better than conventional wood-frame walls.
- This reduces monthly fuel bills. It also allows use of smaller heating and cooling equipment, saving money in construction.

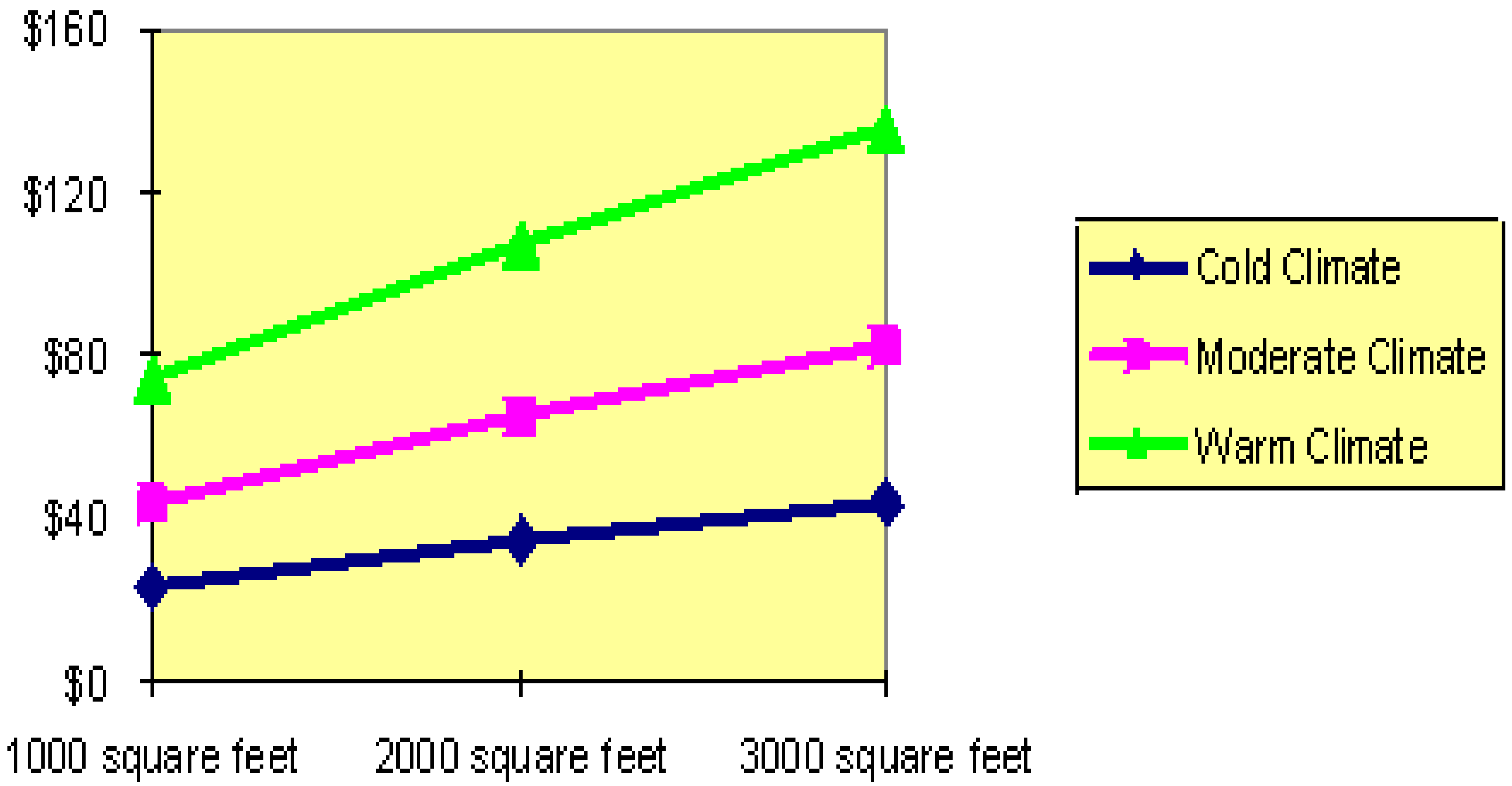
Concrete Homes Save Energy cont.

- Houses built with ICF exterior walls require an estimated 44% less energy to heat and 32% less energy to cool than comparable frame houses. A typical 2,000 square foot home in the center of the U.S. will save approximately $200 in heating costs each year and $65 in air conditioning each year.
- The bigger the house, the bigger the savings. In colder areas of the U.S. and Canada, heating savings will be more and cooling savings less. In hotter areas, heating savings will be less and cooling savings more.

Estimated Annual Savings for Heating ICF Structures



Estimated Annual Savings for Cooling ICF Structures



Energy Savings Estimates

- The above energy savings estimates are from a study of 58 single-family houses across the US and Canada.
- Half had exterior walls constructed with concrete using ICFs made of expanded polystyrene (EPS) or extruded polystyrene (XPS) foam.
- The other half were neighboring houses with wood-frame walls. All houses were less than 6 years old.

Reducing Energy Consumption

- Researchers compared the energy bill of each concrete house to its frame counterpart, carefully correcting for important differences to get an "apples-to-apples" comparison.
- Estimates of equipment savings are actual numbers reported by contractors who build ICF houses.
- Insulating values for ICF walls using polystyrene foam are R-17 to R-26, compared to wood frame's R-9 to R-15. ICF walls are expected to cut conduction losses through foundation and above-grade walls in half. And ICF walls are tighter. In tests, they averaged about half as much infiltration (air leakage) as wood-frame homes.

PHMH Construction

- Since the PHMH will have ICF exterior walls, interior walls, slab floors, and roof, it will have nearly double the insulation [e.g., R-49 (R-43 + R-6 InsulStone) in walls and R-60 (R-16 Quad-Deck panel plus R-44 (8” Foam-Control EPS including 5/8” OSB nail base] in the roof, the increase in energy conservation will be over double that of the ICF houses in the above study.
- In addition, conduction will be virtually eliminated through an air-tight ICF envelope. Thus, the volume of savings for the PHMH will be substantially enhanced in relation to the above comparisons.

Benefits of Interior ICF Walls

- Sound attenuation
- Mold and mildew free environment
- Structural support for ceiling, floors, roof and exterior walls
- Fire resistance (fire protection rating up to 4 hr. via steel reinforced concrete and a non-toxic fire retardant EPS foam)
- Ease of installation and construction including plumbing, electrical, and HVAC, etc.
- Green building & longevity
- Increase in thermal mass

ZNE PHMH

- By virtually eliminating energy losses due to convection and using super-insulated ICF, the primary objective of the PHMH is to decrease the energy load by over 90%. This will reduce HVAC sizing proportionately, possibly allowing for integration of geothermal heat pumps and ERVs.
- Structure orientation, strategic glazing, and passive solar radiation will then be utilized in conjunction with solar/PV power systems to achieve a Zero Net Energy PHMH.

Smaller Energy/HVAC Loads

- Since the energy needed is less, HVAC requirements are also less. And the more the energy savings, the greater the possible reduction in equipment size/cost.
- Estimating the size of heating and cooling equipment for concrete homes can be complicated because the effect of thermal mass must be simulated in a computer program.
- The Building Energy Optimizer (BEopt) modeling software and Energy Plus simulation software (developed by NREL) and WrightSoft HVAC software simplify manual J & D calculations by entering information about the house including location, house size and wall, floor, and roof construction, etc.

HVAC Sizing Software

- BEopt and Wrightsoft's sophisticated HVAC design software use Dept. of Energy 2.1E calculations to estimate the required heating and cooling system capacity (Manual J) for single-family concrete homes.
- Calculations are based on a user-defined thermostat set point, house dimensions, construction materials, and geographical location.

Summary of ICF vs. Wood Frame

- The R-value of one component alone does not reveal how a building will perform. The Building Code is only a MINIMUM standard, and there are many factors that influence energy performance.
- ICF buildings far outperform framed buildings despite similar stated R-values.
- The secret lies in the combination of reduced conduction & convection, and high thermal mass.
- The result is ICF buildings have lower appetites for energy and more consistent and comfortable temperatures inside the building.

PHMH Strategy

- NREL's Building Energy Optimizer (BEopt) modeling software and EnergyPlus simulation software will be utilized to optimize energy conservation and reduce energy loss through tight ICF construction, superinsulation, southern orientation, and strategic glazing, etc.
- Integration of passive solar radiation and the relatively high thermal mass of exclusive ICF structures including radiant floors allows for providing unprecedented energy conservation.

State-of-the-Art Modeling & Simulation Software

- The PHMH will be designed using BEopt modeling software and the EnergyPlus simulation engine developed by DOE’s National Renewable Energy Lab (NREL).
- This software is publicly available and is constantly being updated and improved, the goal of which is to assist builders and homeowners to achieve unprecedented levels of energy efficiency in an affordable manner.

Achieving Zero Net Energy (NZE)

- BEopt is a computer program designed to find cost-optimal building designs along the path to a zero net energy (ZNE) building.
- A zero net energy building produces as much energy as it uses on an annual basis, using a grid-tied, net-metered photovoltaic (PV) system and active solar.
- The optimal path to ZNE extends from a base case to the ZNE building through a series of energy-saving building designs with minimal energy-related costs.

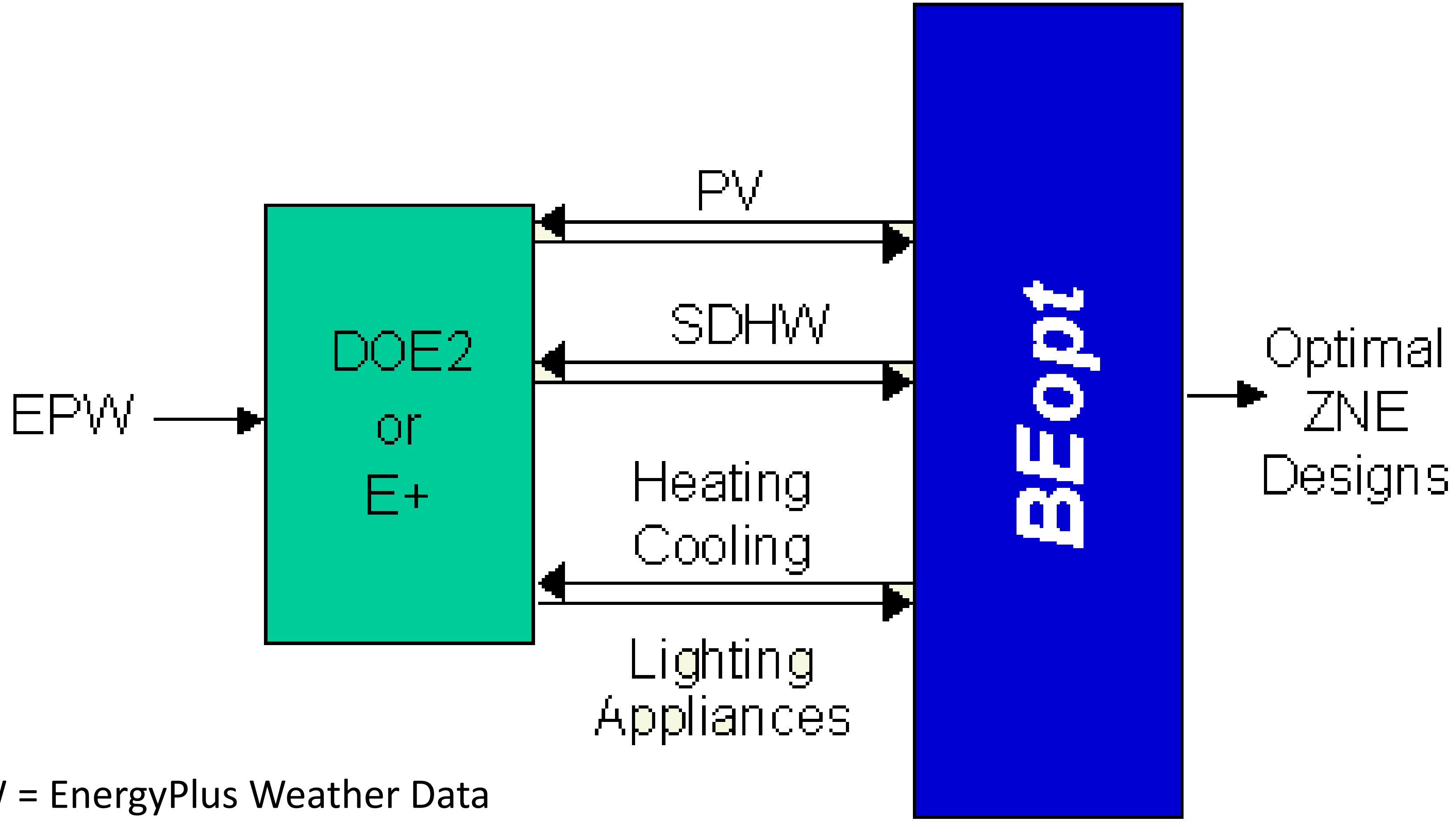
BEopt Modeling Software

- In BEopt, a user selects from predefined options in various categories to specify options to be considered in the optimization.
- Energy savings are calculated relative to a reference. The reference can be either a user-defined reference, a climate-specific Building America Benchmark for new construction, or an Existing (w/ Min Replace) reference for retrofit.
- The user can also review and modify detailed information on all available options via the library management tools.

DOE2 or EnergyPlus Simulation Engines

- BEopt calls the DOE2 or EnergyPlus simulation engines and uses a sequential search technique to automate the process of identifying optimal building designs along the path to ZNE.
- BEopt finds these optimal designs based on discrete building options reflecting realistic construction options.
- BEopt handles special situations with positive or negative interactions between options in different categories.

BEopt & E+ Flow Chart



EPW = EnergyPlus Weather Data
PV = Photovoltaic Power System
SDHW = Solar Domestic Hot Water

Output Screen

- The BEopt software includes an output screen that allows the user to navigate among different design points and retrieve detailed results regarding energy end-use and option costs in different categories.
- Multiple cases, based on a selected parameter such as climate, can be included in a BEopt project for comparative purposes.

Modes of Analysis

- Currently there are three modes of analysis: design mode, parametric mode, and optimization mode.
- Design mode allows the user to perform a set of building design simulations for analysis.
- Parametric mode allows the user to quickly perform traditional parametric analyses.
- Optimization mode, on the other hand, sequentially searches the available building options for the lowest cost building designs at various levels of energy savings.

Minimizing PV Investment

- Before investing in photovoltaic technology to produce a home's energy, it is more cost-effective to first use energy efficient measures to minimize the energy that must be produced.
- In this way, a smaller, less expensive PV array can meet the home's energy needs.

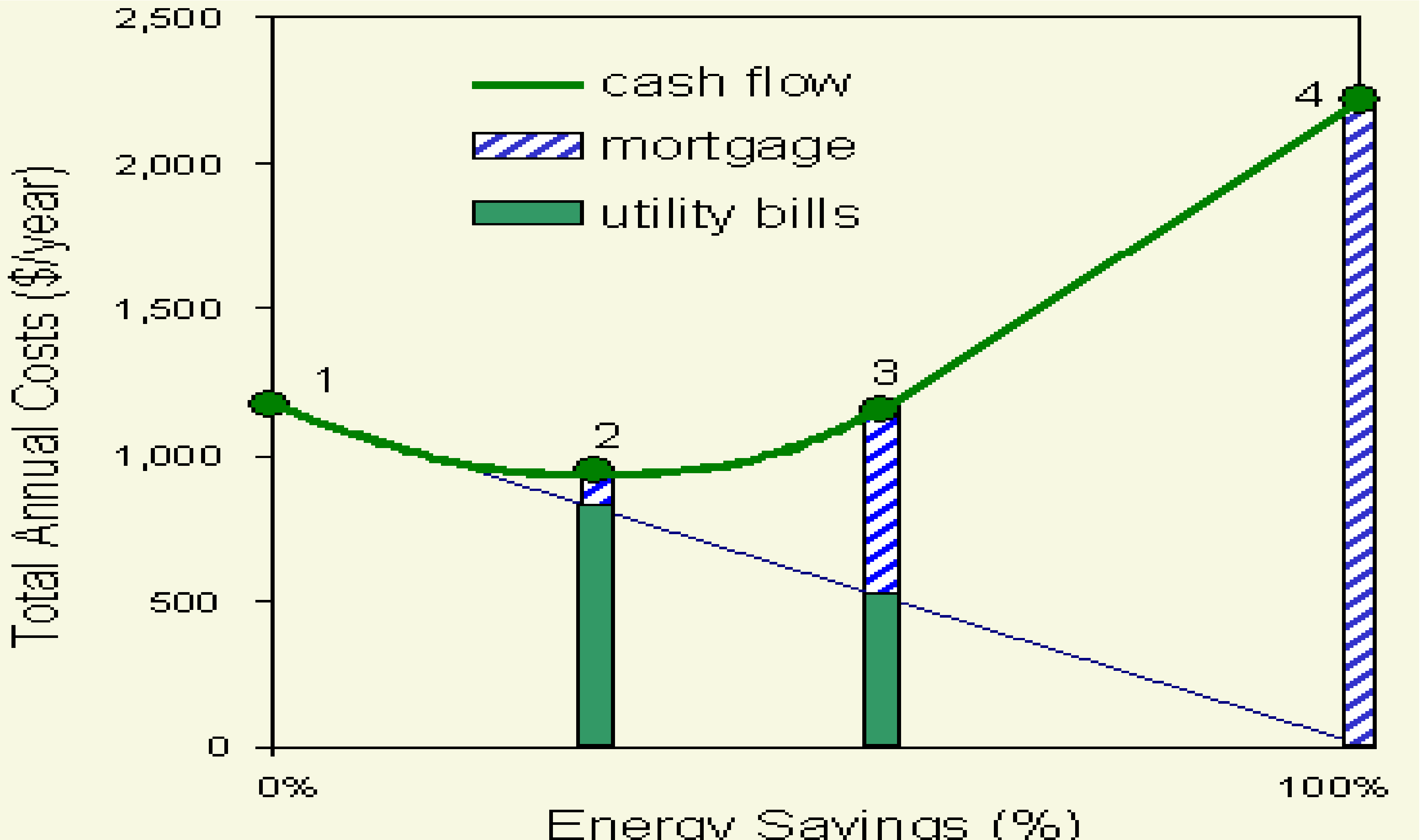
Path to Zero Net Energy

- BEopt produces a graph referred to as the Path to Zero Net Energy. This Path can answer the following questions:
  - How much should be invested in efficiency before investing in PV?
  - What is the optimal configuration of energy efficiency measures?
  - What if only a partial reduction in energy use (from a reference case) is desired?

Path to Zero Net Energy cont.

- The following sketch illustrates the concept of a building's path to zero net energy.
- The path falls on a graph of the % energy savings along the x-axis, and the annualized energy costs on the y-axis.
- This annual cost is made up of both the energy costs each year plus the cost of energy efficiency measures that have been incorporated into the mortgage payments.

Path to Zero Net Energy Graph



PHMH Objectives

- BEopt and EnergyPlus software will be used to achieve one of the primary objectives of the PHMH, e.g., initial planning and design.
- This will include analysis and adoption of leading edge technologies in conjunction with construction management techniques that will provide a paradigm shift in:
  - Energy Efficiency
  - Quality
  - Affordability

Passive Building Design

- Every building must be considered from a 'whole system' perspective.
- In addition to walls, roof and slab, windows have a significant impact on performance.
- Windows usually make up 10-20% of the total wall area and range widely in energy efficiency.

Building Envelope & Computer Analysis

- Building envelope consultants now offer modeling services (such as BEopt and Energy Plus) that provide an accurate picture of how a building will actually perform after construction.
- This small investment in computer analysis assists in formulating the most energy efficient design in order to save tens of thousands - even hundreds of thousands - in energy costs over a building's lifetime.

Green Building & Passive House Design

- Sustainable or green building practices promote the construction of buildings that are healthier for the occupants and healthier for the environment.
- They reduce the tremendous impact that building construction, operation, maintenance, and disposal have on both people and nature.
- According to the US Department of Energy's Center for Sustainable Development, buildings consume 40-50% of the world's total energy, 25% of its wood harvest and 16% of its water.
- The building industry is the nation's largest manufacturing activity, representing more than 50% of the nation's wealth.

Green Building & ICF Technology

- A recent report by the Commission for Environmental Cooperation (CEC) promotes Green Building for the Biggest, Easiest Cuts in CO_2 Emissions.
- Energy-saving technologies applied in buildings can result in enormous reductions in demand for fossil fuels and emissions of greenhouse gases.
- ICFs are a key technology because they provide an ultra-efficient, high mass, high strength, and a very tight, durable building shell that keeps occupants healthy and comfortable while having a very small environmental footprint.

Boise, ID Passive House Planning

- Boise, ID is located in a zone 5 arid environment with temperate climate.
- Summers are typically hot and dry from July to September with a relatively large temperature swing in the evenings.
- The summer temperature swing is ideal for capitalizing on cooling the interior of the structure during the evenings/early mornings.
- The angle of the sun in the summer and winter is ideal for capitalizing on solar passive gain in the winter.

Passive House Planning

OFFICIAL CLIMATE DATA SET - PHIUS

METRIC:					
Month	11	12	Heating Load		Cooling Load
Days	30	31	Weather 1	Weather 2	Radiation
BOISE AIR TERMINAL [UO] ID	Radiation Data:	kWh/(m²*month)	Radiation: W/m²		W/m²
Ambient Temp (°C)	4.0	1.9	-9.9	4.0	27.5
North	18.0	17.0	39.0	16.0	82.0
East	39.0	34.0	78.0	25.0	204.0
South	93.0	89.0	179.0	43.0	145.0
West	40.0	34.0	71.0	23.0	195.0
Global	55.0	44.0	85.0	33.0	330.0
Dewpoint	-1.9	-3.3			
Sky temperature	-10.2	-12.3			

US CUSTOMARY:					
Month	11	12	Heating Load		Cooling Load
Days	30	31	Weather 1	Weather 2	Radiation

Passive House Design Requirements

- Total heating & cooling demand of <15 kWh/m^2/yr (4.7 kBtu/ft^2/yr)
- Total primary (i.e., source) energy of <120 kWh/m^2/yr (38 kBtu/ft^2/yr)
- Air-tightness <0.5 ACH@50 Pa or less
- Peak heating demand <10 W/m^2 (3.2 Btu/ft^2)
- Total site energy of <42 kWh/m^2/yr (13.3 kBtu/ ft^2/yr)
- Window U_{si}-values of <0.8 W/m^{2}K (0.15 Btu/ ft^2/F, R_{ip}-7.1)
- High-efficiency heat recovery (over 80%)

Passive House U-value Requirements

- The International Passive House requirement for U-values is typically in the 0.10 to 0.15 W/(m².K) range).
- In Sweden, to achieve passive house standards the U_{si}-value is 0.066 W/(m².K)).
- In Boise, ID, to achieve passive house standards the insulation U_{si}-value target is <0.12.

SI & IP Standards for R-Values and U-Values

- Around most of the world, R-values are given in SI units (International System of Units), typically square-meter kelvins per watt or $m^2 \cdot K/W$ (or equally, $m^2 \cdot °C/W$).
- In the United States customary units, R-values are given in units of $ft^2 \cdot °F \cdot hr/Btu$.

SI & IP Conversion Formula

- It is particularly easy to confuse SI and US/North American R-values (IP), because R-values both in the US and elsewhere are often cited without their units, e.g., *R-3.5*.
- Usually, however, the correct units can be inferred from the context and from the magnitudes of the values. United States and North American R_{ip}-values are approximately six times R_{si}-values.
- The specific conversion formula is: $U_{si} = U_{ip} * 5.678263$.

Boise, ID Passive House Objectives

- Insulation, >R_{ip}-51 (<U_{si}-0.111) walls, R_{ip}-60 (U_{si}-0.0710) roof, quadruple-glazed R_{ip}-9 low-e windows, and elimination of thermal bridges via ICF construction (exterior foam and interior concrete).
- Ultra-airtight construction (<0.5 ACH@50) and U_{si}-value wall requirements (<0.12) will be accomplished using a rectangular structure shape with southern orientation.

Boise, ID Passive House Objectives cont.

- Normally R_{ip}-45 (U_{si}-0.1262) sub-slab insulation is recommended for passive house design.
- However, for the desert environment which provides relatively cool soil temperatures, provides a strategic advantage for passive cooling of structures in the summer without significantly affecting winter heating loads.
- Hence, insulation in the basement floor slab can virtually be eliminated.
- Passive solar gain for a portion of the heating will be achieved by orienting the house to the south and using a passive window solar heat gain coefficient (SHGC) score of near 0.50.

Boise, ID Passive House Objectives cont.

- UltimateAir RecoupAerator ERV to reach 96% efficiency via EC motor, with supply air to each space and strategic return air ducts/pathways integrated with the GSHP and air handler system.
- A water to water GSHP, hydronic-radiant floor heating and cooling, 2nd stage air handler system to manage humidity and supplement radiant floor system with additional supply and strategic return air ducts/pathways.
- Solar thermal and thermal battery system including a relatively large concrete cistern and oversized geothermal with ability to store the majority of solar thermal energy not utilized during the warm season.
- Solar PV system to provide ZNE, and possibly a battery system and sterling engine for generating off-grid power.

InsulStone R_{ip}-6, R_{ip}-11, R_{ip}-15.5

- Using insulated cultured stone and stucco products for the exterior of the PHMH will allow for increasing the total insulation value of walls from R_{ip}-43 (TMO Quad-Lock panels) to R_{ip}-49 (U_{si}-0.1159), R_{ip}-54 (U_{si}-0.1051), or R_{ip}-58.5 (U_{si}-0.0971) with finished exterior. Cost of the InsulStone product is $7.64, $8.54, and $10.80/sqft, respectively.

InsulStone Concrete Product
Glued to Quad-Lock ICF Panel

Using a proprietary adhesive developed in collaboration with Dow Chemicals, it works equally well with either foam or cultured stone products.

Pull Test – 120 lb. psi – withstands hurricane strength winds

InsulStone Exterior Finish

- The wood block inserted into the concrete core would probably eliminate the need for metal brackets extending up through the foam and attaching to the window.
- A non-metallic or PVC flashing material would slant down over the EPS foam exterior and would be covered by an InsulStone (EPS insulated cultured stone using screws or staples to attach to EPS ICF exterior) exterior finish.
- Insulstone can be installed up to ten times faster than conventional masonry products.

NUDURA & Quad-Deck ICF Technologies

- Quad-Lock is ISO 9001 and 14001 certified to ensure and continually improve product and service quality, and have minimal impact on our environment.
- NUDURA & Quad-Lock ICF hybrid blocks and panels are constructed of dense Expanded Polystyrene (EPS) foam insulation that is fire retardant and mold-free [includes injection molded high-density polyethelene cross ties spaced at 12” (305 mm) on center horizontally].

NUDURA & Quad-Lock Distribution & Training

- NUDURA & Quad-Lock will be contributing ICF hybrid block and panel materials for building and demonstrating passive house design via a model home.
- RM Enterprises, LLC will become a distributor for NUDURA & Quad-Deck products.
- RM Enterprises and general contractors trained and certified in NUDURA & Quad-Lock technologies will train other contractors and subcontractors on installation of ICF and other technologies utilized in the passive home/building design.

NUDURA & Quad-Deck ICF vs. Wood Frame Construction

- Ultra Energy-Efficient because of continuous EPS insulation (higher & uniform R-value), greatly reduced air infiltration, and the thermal mass effect of concrete.
- More comfortable and healthy because of even inside temperatures (no cold spots or nasty drafts), far better sound attenuation, and low risk of mold growth and allergen infiltration.
- Longer-lasting and more resistant to natural disasters, rot, mold, and pests because the solid reinforced concrete is up to 8 times stronger and nearly impenetrable (even for car crashes) - it's what gives bunkers their strength!

NUDURA & Quad-Lock ICF vs. other Insulating Concrete Form Manufacturers

- Quad-Lock has the highest range of insulation values.
- Different combinations of Quad-Lock panel provide true R-Values of 22, 28, 30, 38, 43, 45, 53, and 59.
- Be wary of "effective R-Values" (often cited as R-50 for R-22 ICFs) which are unscientific and prohibited by advertising laws.
- Integration of NUDURA and InsulStone products can achieve or exceed the R-values provided by Quad-Lock and other ICF wall building systems.

NUDURA & Quad-Deck ICF vs. other Insulating Concrete Forms Cont.

- NUDURA & Quad-Deck creates much less waste compared to ICF block systems because most parts that need to be cut can be reused in the same project (see Reduce, Reuse & Recycle Tips).
- NUDURA & Quad-Lock typically add a **2-4%** waste factor in estimates (some installers can achieve 1% or less!), while many projects using ICF blocks need a **5-8%** waste factor - often not included in estimates.

NUDURA & Quad-Deck ICF vs. other Insulating Concrete Forms Cont.

- A price per square foot of forms is NOT suitable for comparisons because you need to add the waste factor, structural bracing for corners and angles, plywood wrap-arounds on openings, zip-ties or clips to hold ICF blocks together, method to align walls along top and bottom, etc. along with associated labor costs!

NUDURA & Quad-Deck ICF vs. other Insulating Concrete Forms Cont.

- Most NUDURA items are in stock ready for shipping whereas many competitors require long lead times to first produce what you order; in addition it means their forms are often still moist and not shrunk down to final size.
- NUDURA offers less thermal bridging because internal buck-outs are made easy. "External bucks" - the only option for most ICF blocks - create a significant thermal bridge around every window and door opening.

OSB for Door & Window Buck-outs

- For the PHMH, internal buck-outs and subsequent framing of windows and doors will utilize relatively higher R-values for oriented strand board (OSB) materials vs. conventional 2x6 or 2x8 fir or pine studs.
- Expanding spray foam will also be utilized to provide an air tight and well insulated installation of windows and door frames.

Quad-Lock ICF vs. other Insulating Concrete Forms Cont.

- Quad-Lock is highly versatile using standard parts. Quad-Lock can easily be shaped to form all the design elements of modern buildings - wide openings, arches, corners, any angles, and real curves with almost any radius.
- Quad-Lock produces a flat, solid concrete wall providing a constant thickness of concrete throughout the wall (no thin/thick sections like grid or post-and-beam systems).

Quad-Lock ICF vs. other Insulating Concrete Forms Cont.

- Quad-Lock is Code Approved.
- Quad-Lock provides a better surface for stucco application. Quad-Lock creates an all-foam surface compared to some ICF systems where the surface consists of both EPS and the material used for ties, making it tougher to finish it.
- Quad-Lock's unique and patented tie design offers low likelihood of problems by positively connecting the EPS panels at both the horizontal and vertical seams where the pressure during concrete placement is most likely to cause failures.

Quad-Lock ICF vs other Insulating Concrete Forms Cont.

- Quad-Lock has very strong corners because of ingenious metal brackets - no additional bracing or zip-ties needed!
- Quad-Lock costs less to ship and store compared to most ICF block systems because it is a flat panel & tie system.
- Up to 100% more wall area can be shipped per truckload. With Quad-Lock, you're not shipping air!

Quad-Lock ICF vs other Insulating Concrete Forms Cont.

- Quad-Lock is ISO 9001 and 14001 certified to ensure and improve product and service quality and minimal impact on our enviroment.
- Quad-Lock offers great technical and instructional support and material. Local dealers and distribution partners are equipped to answer your questions, prepare detailed estimates, and assist at the jobsite.
- Quad-Lock Field Representatives are also ready to assist with quantity pricing, job site training, product seminars etc. Their website, Installation Video, Product Manual, and other informative technical and promotional literature reveal exactly how to build with Quad-Lock.

Commercial & Multi-Story Advantages over other ICFs

- No other ICF can build around pre-tied rebar as easily as Quad-Lock.
- No other ICF can be assembled with as little laborers' exposure to the outside of a multi-story structure.
- Quad-Lock's unique Corner, Angle, and T-wall solutions allow building from the safety of the inside of the building. This minimizes the amount of outside scaffolding required and the risk of long falls for workers.

Commercial & Multi-Story Advantages over other ICFs

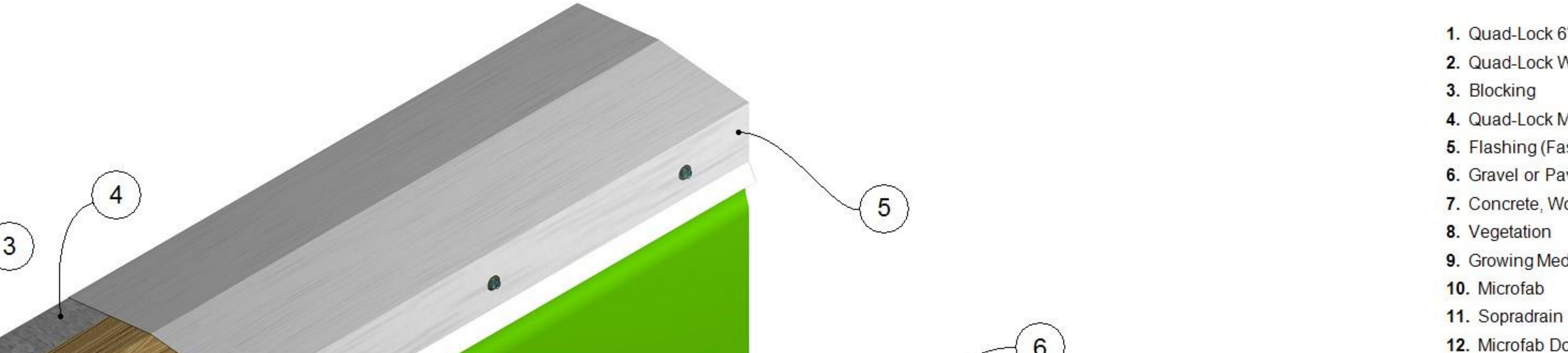
- No other ICF can build columns and pilasters like Quad-Lock. Almost every commercial project needs them.
- Few other ICFs can offer the range of wall thicknesses that Quad-Lock offers. See Quad-Lock Ties & Extender Ties.
- No other ICF can provide Quad-Lock's unlimited range of wall angles with so little labor.

Commercial & Multi-Story - Advantages over other ICFs cont.

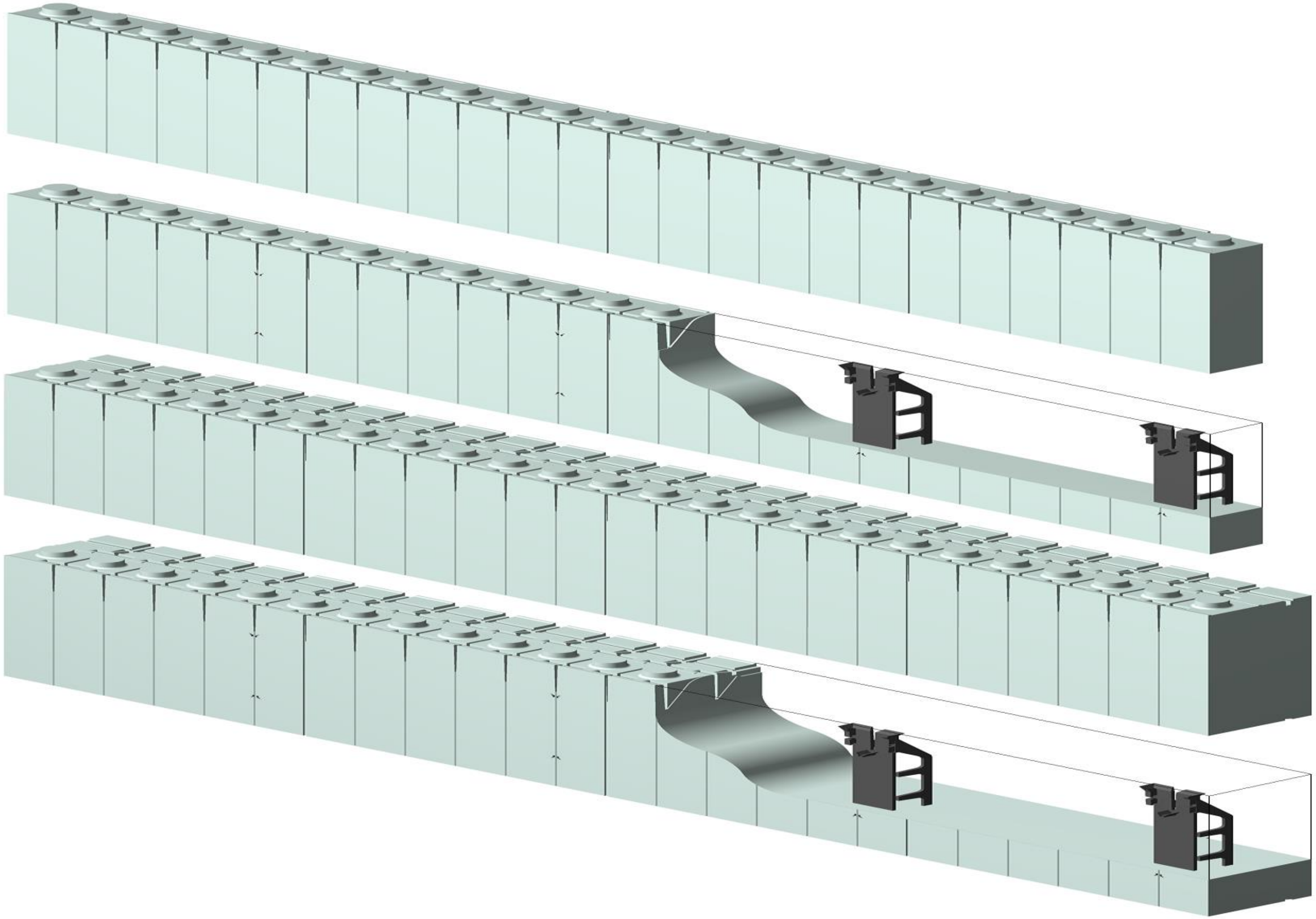
- No other ICF integrates concrete walls and concrete floors or roofs as well. Quad-Lock developed and tested unique solutions, such as Slab Brackets & Ties, and actively sells and supports an ICF for concrete floors & roofs, allowing lower freight costs by combining wall and floor shipments.
- Few other ICF companies offer access to a LEED AP (Accredited Professional) who can help designers identify & accrue LEED points for Quad-Lock projects.

Quad-Lock Green Roof Technology

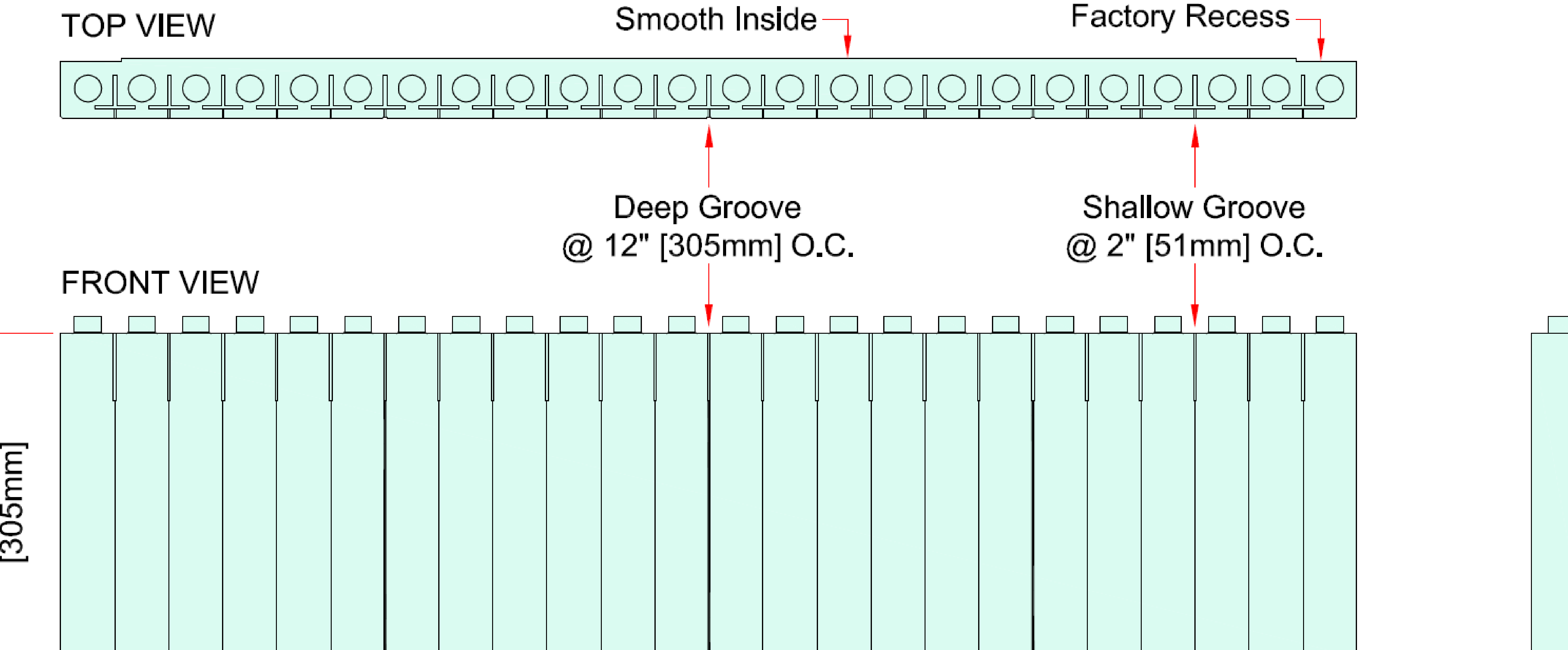
- Quad-Lock offers Green Roof technology with a rot-resistant roof structure that will carry the loads imposed by these designs. Learn more about Green Roofs.



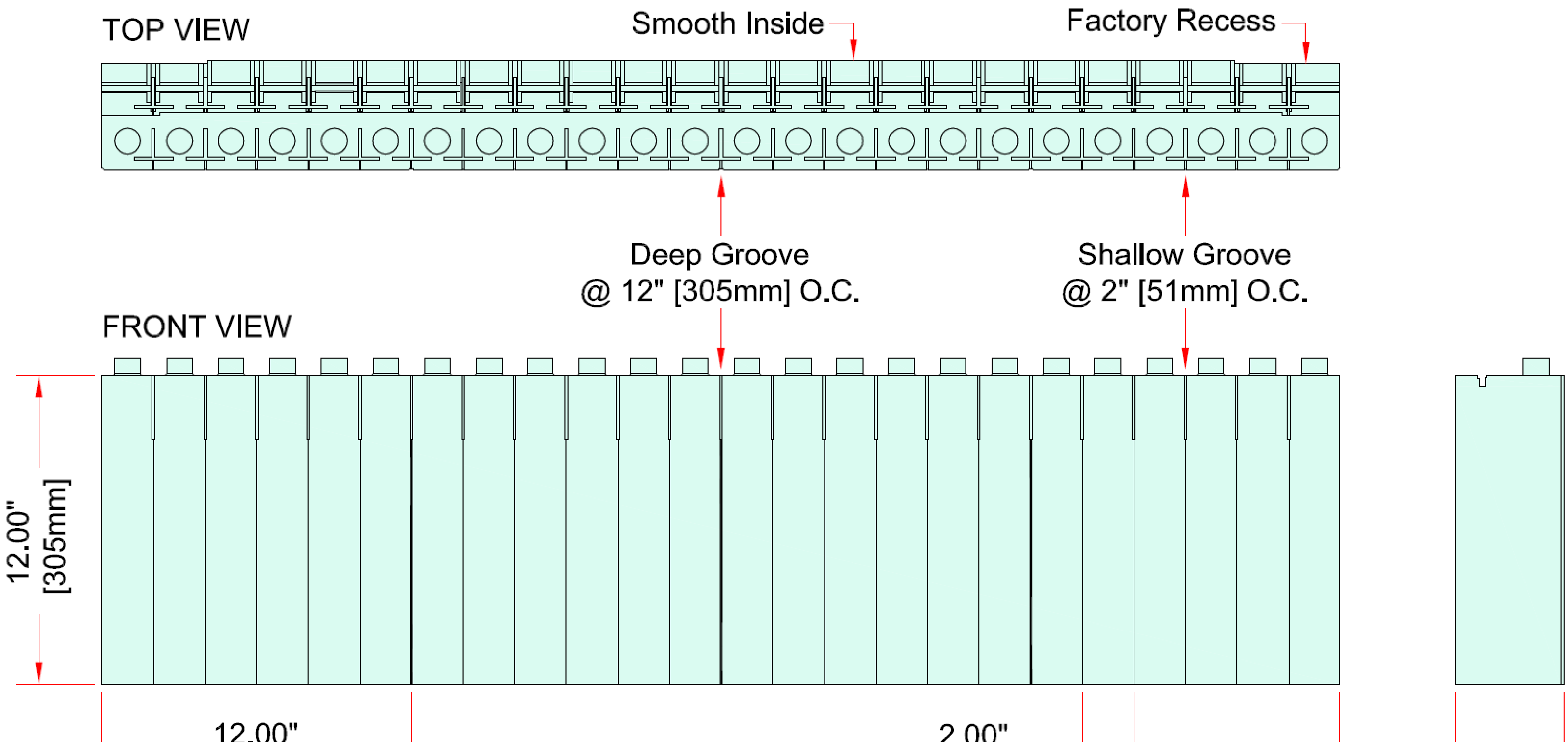
Quad-Lock ICF Wall Panel Design



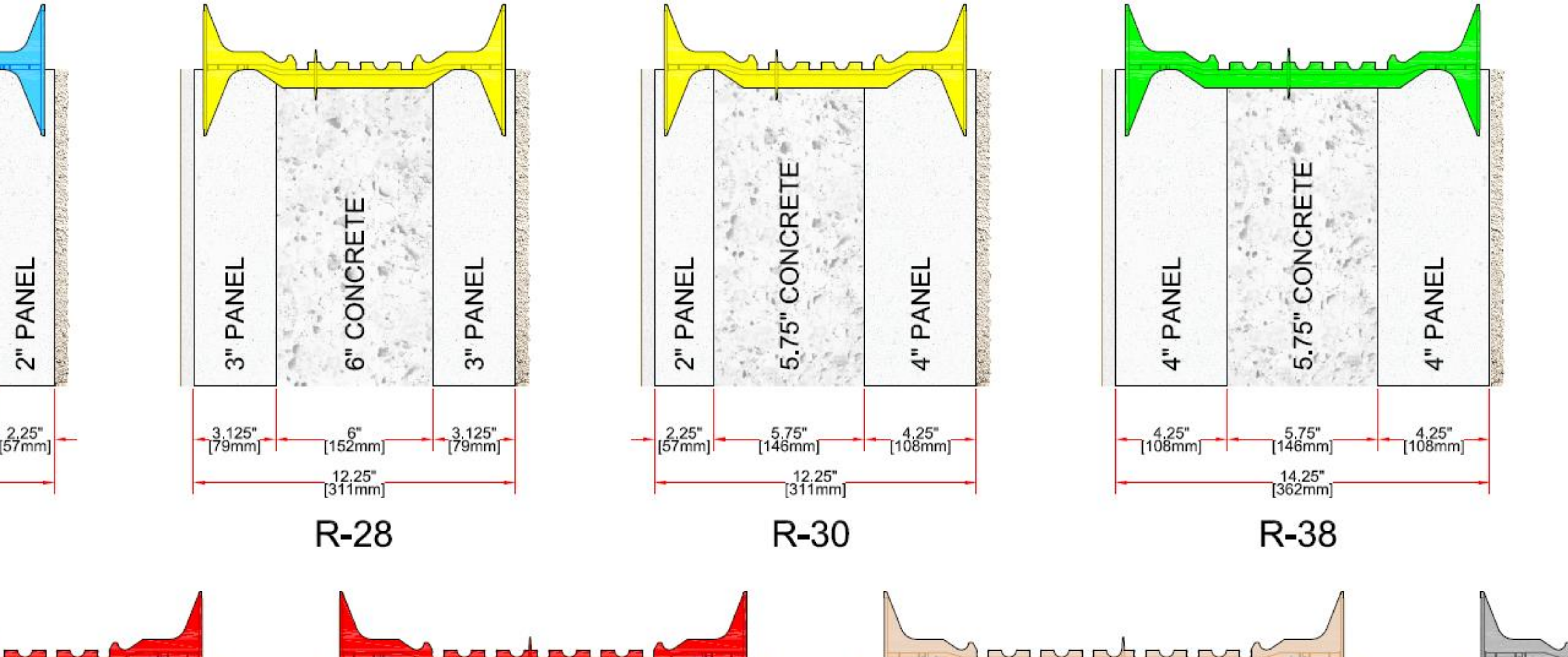
Quad-Lock Panel Dimensions



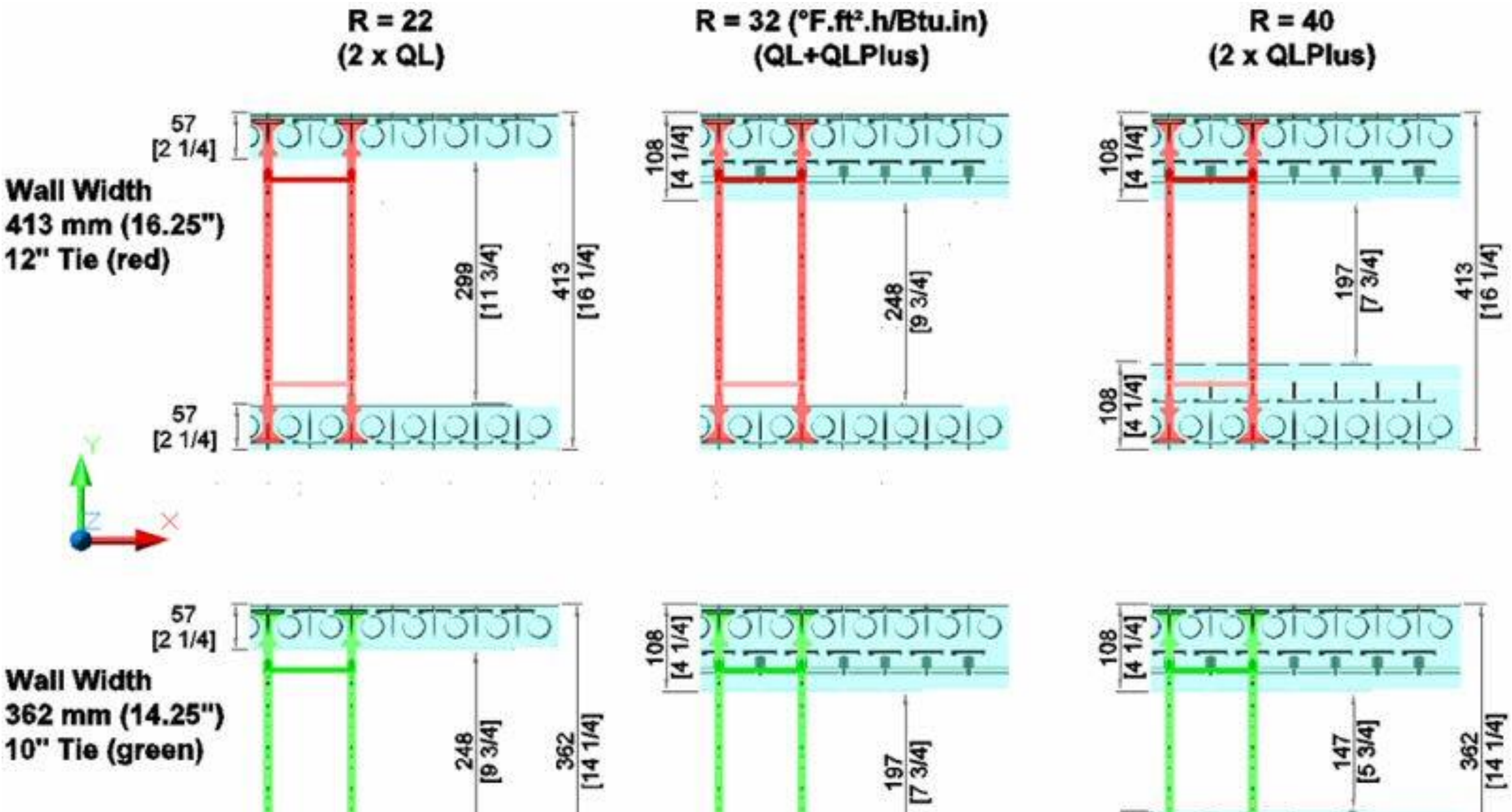
Quad-Lock Plus Panel Dimensions



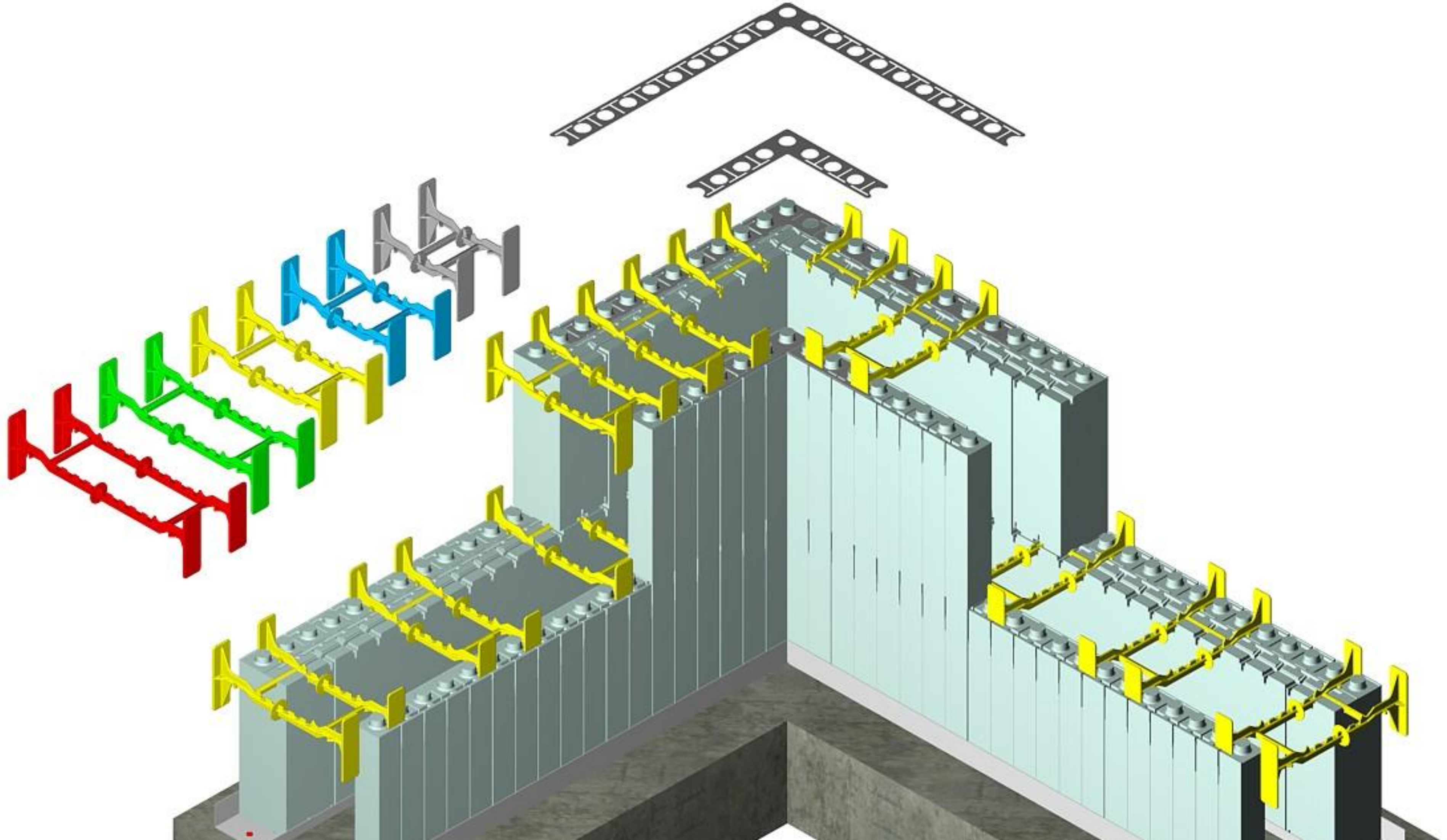
Quad-Lock Wall Panel Configurations & Dimensions



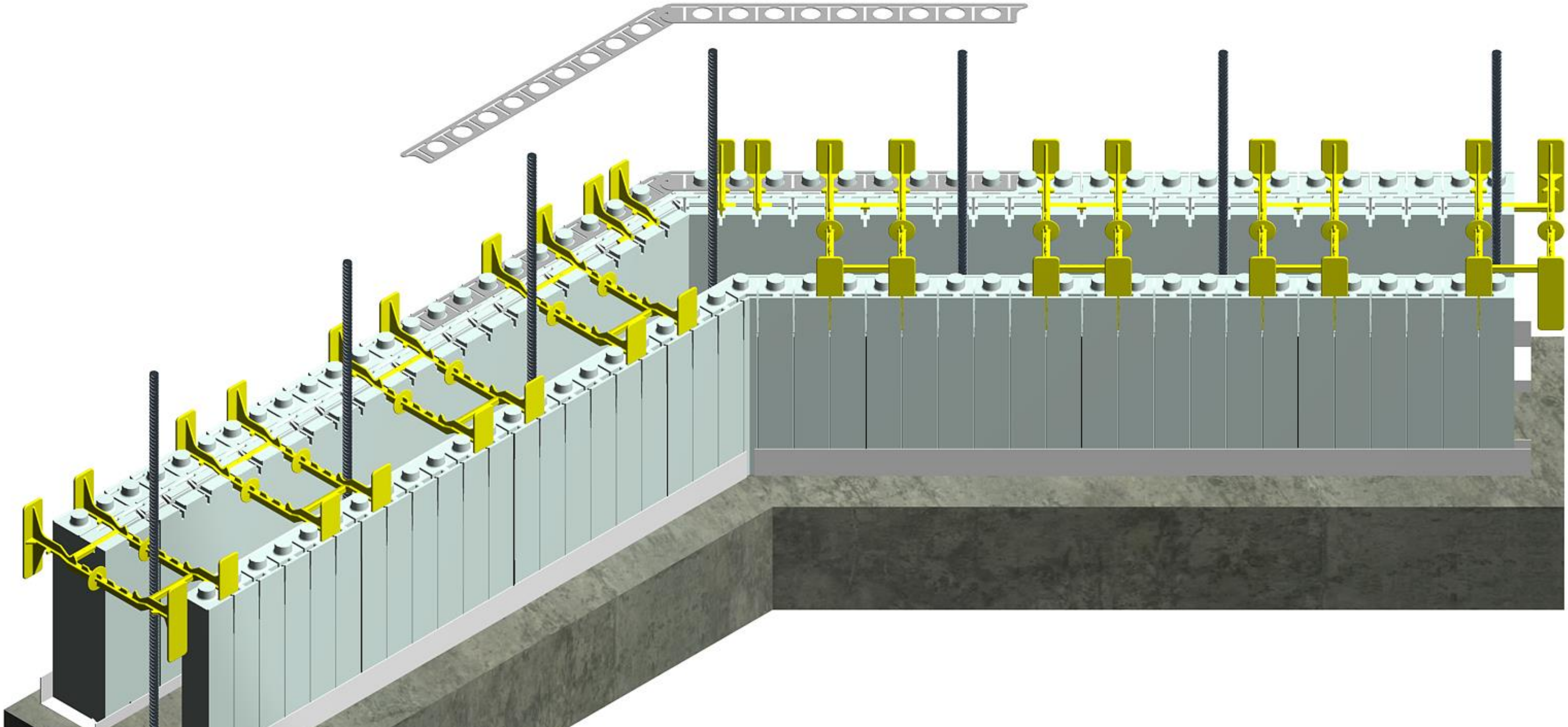
Additional Quad-Lock Configuration Data



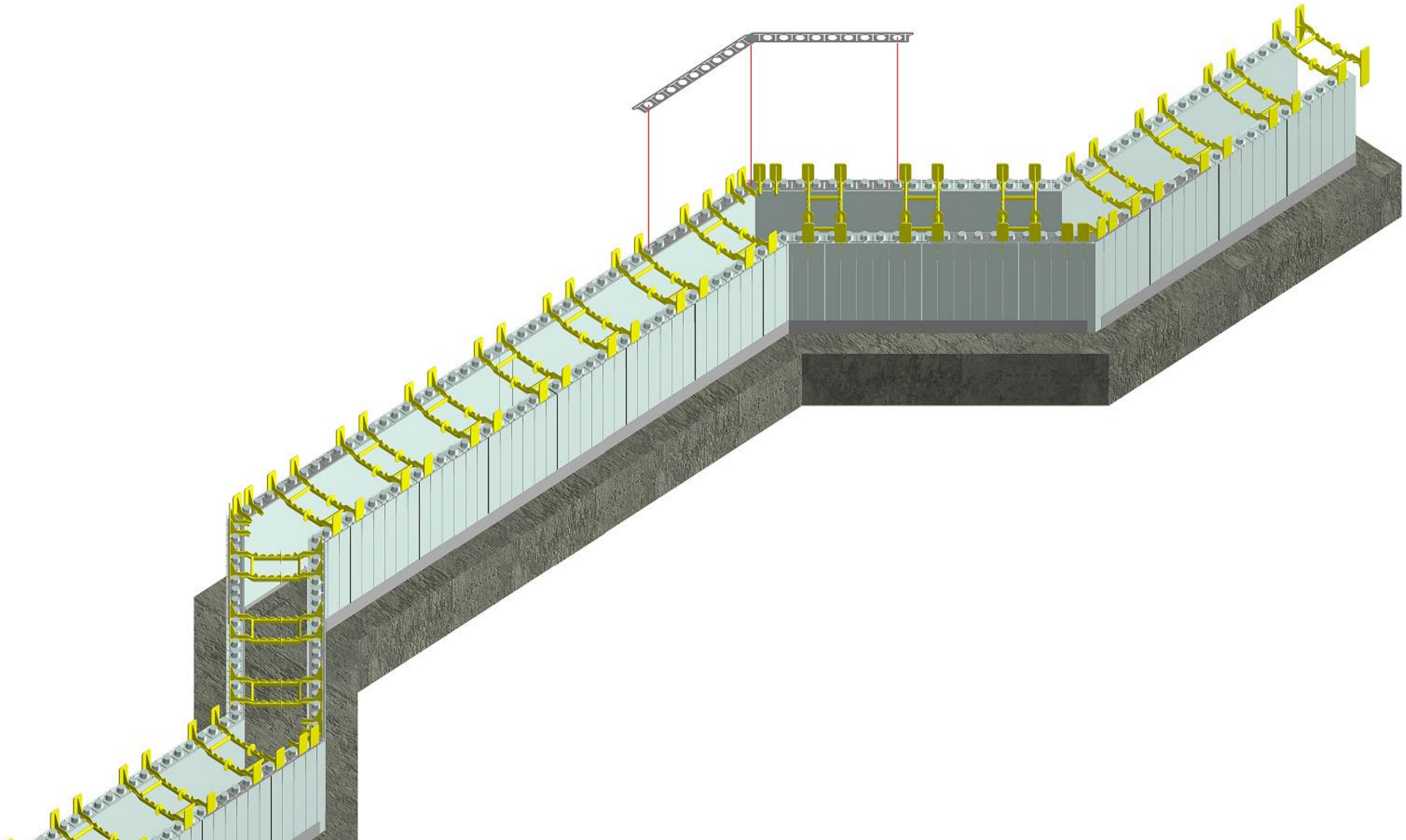
Quad-Lock Plus Corner



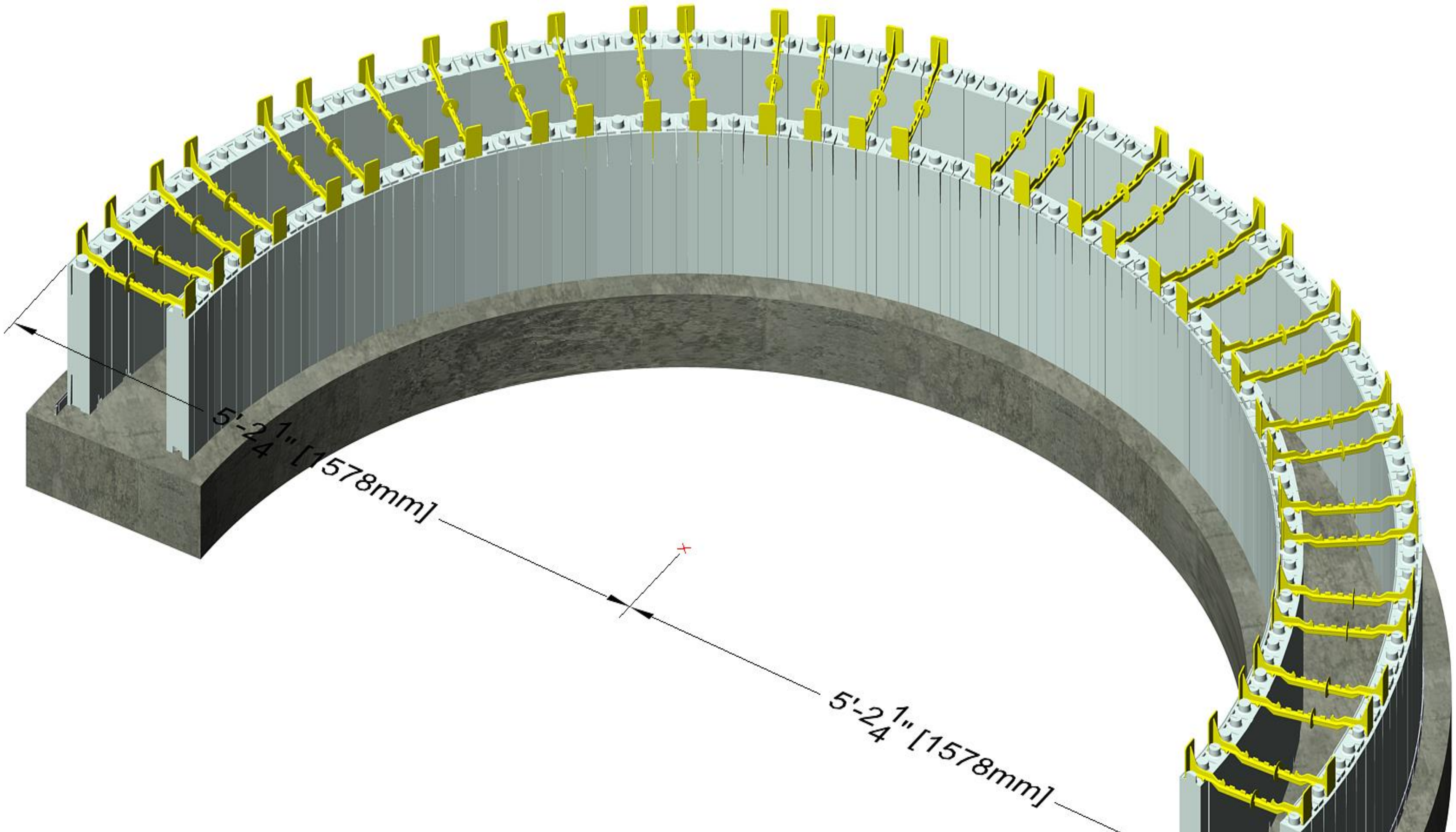
Quad-Lock Plus Angle



Quad-Lock Bay Window



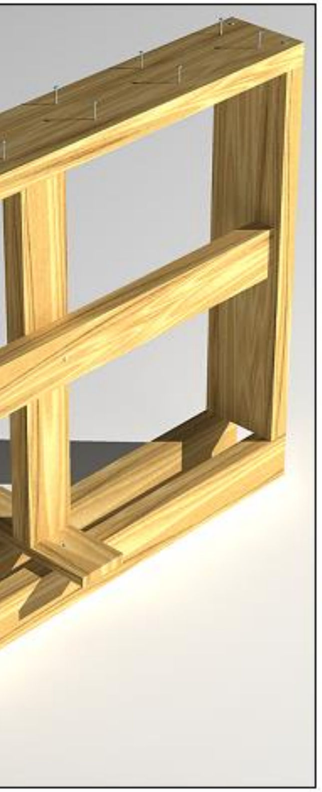
Quad-Lock Radius

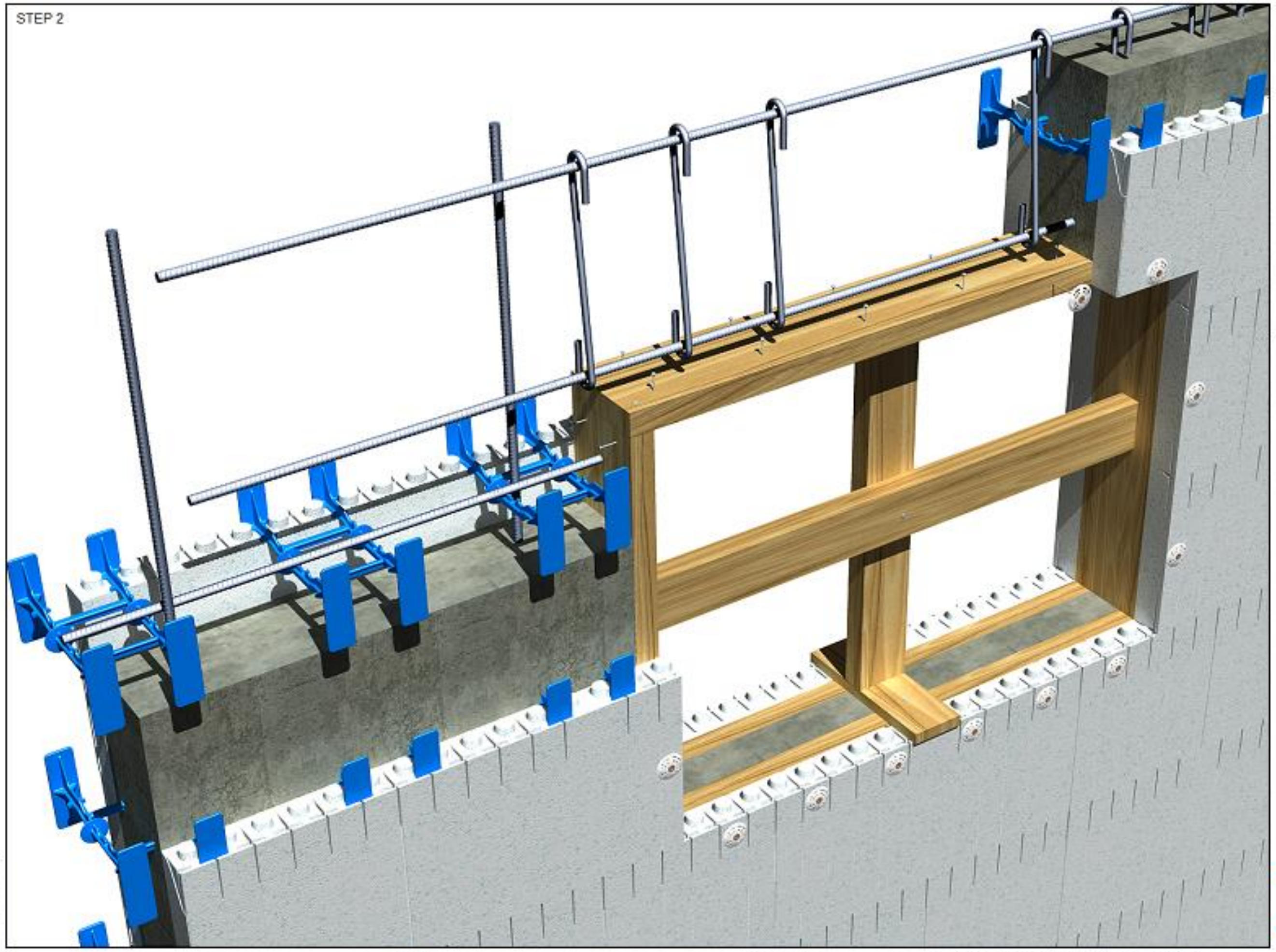


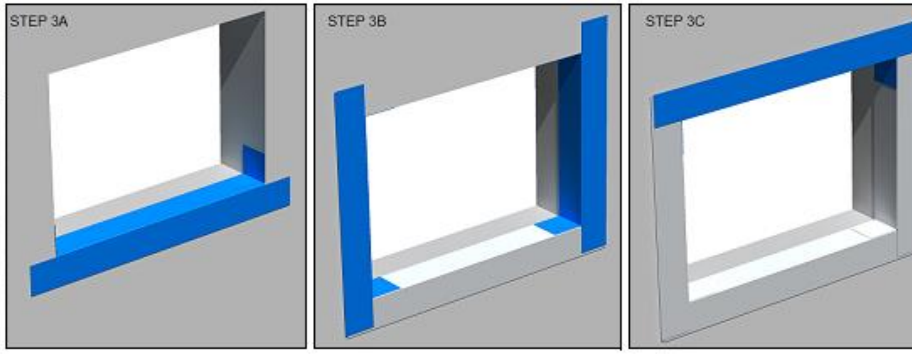
Quad-Lock Radius Staircase & Quad-Deck Floor

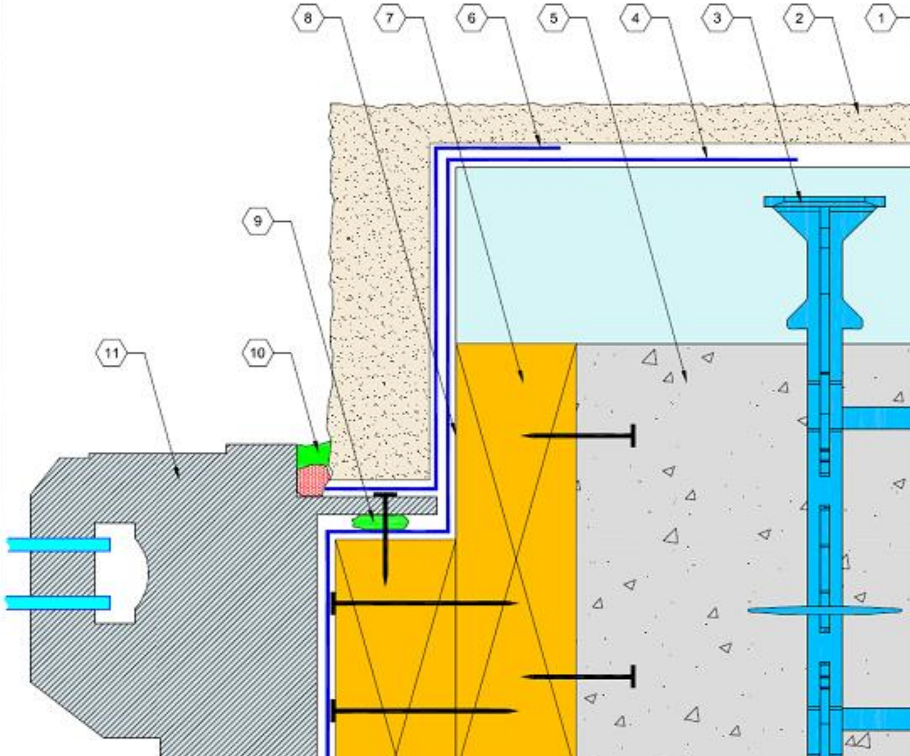
Quad-Lock Arched Openings

Quad-Lock Internal Window Buck









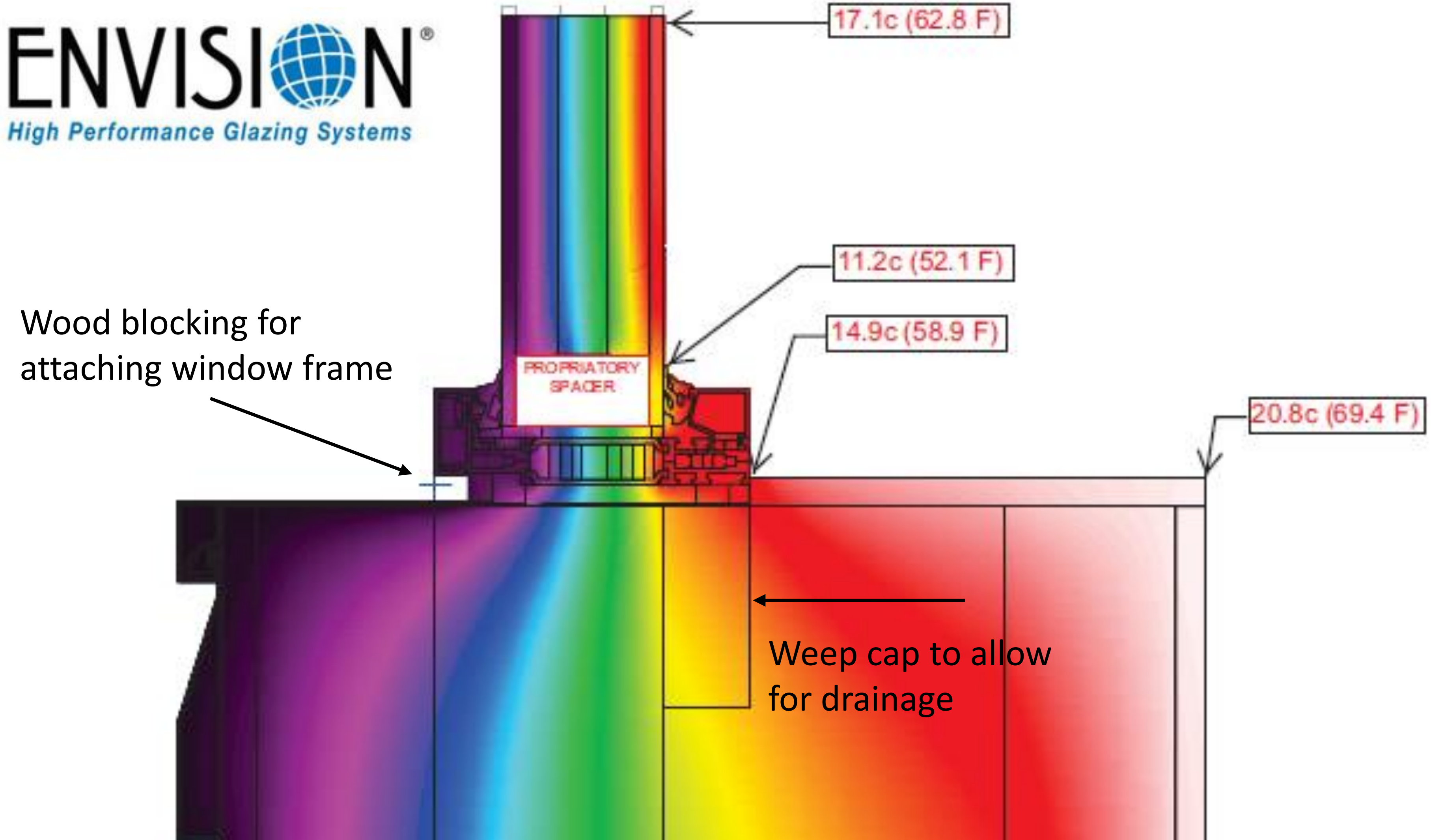
Improved Rigid Urethane Foam Installation for ICF Windows

- A similar though smaller wood block with more foam system (that was anchored to the concrete core) could be used to attach to the window. The slot in the bottom section of the internal buck is used to insure that a good concrete fill is achieved during pouring.
- In addition to the window buck, each of the steps for installation are listed (which would be similar for the R-43 ICF configuration). However, we will use 3” rigid urethane foam cut to size to insulate the core concrete before the window installation in order to eliminate the thermal break created by the pressure treated wood blocking.

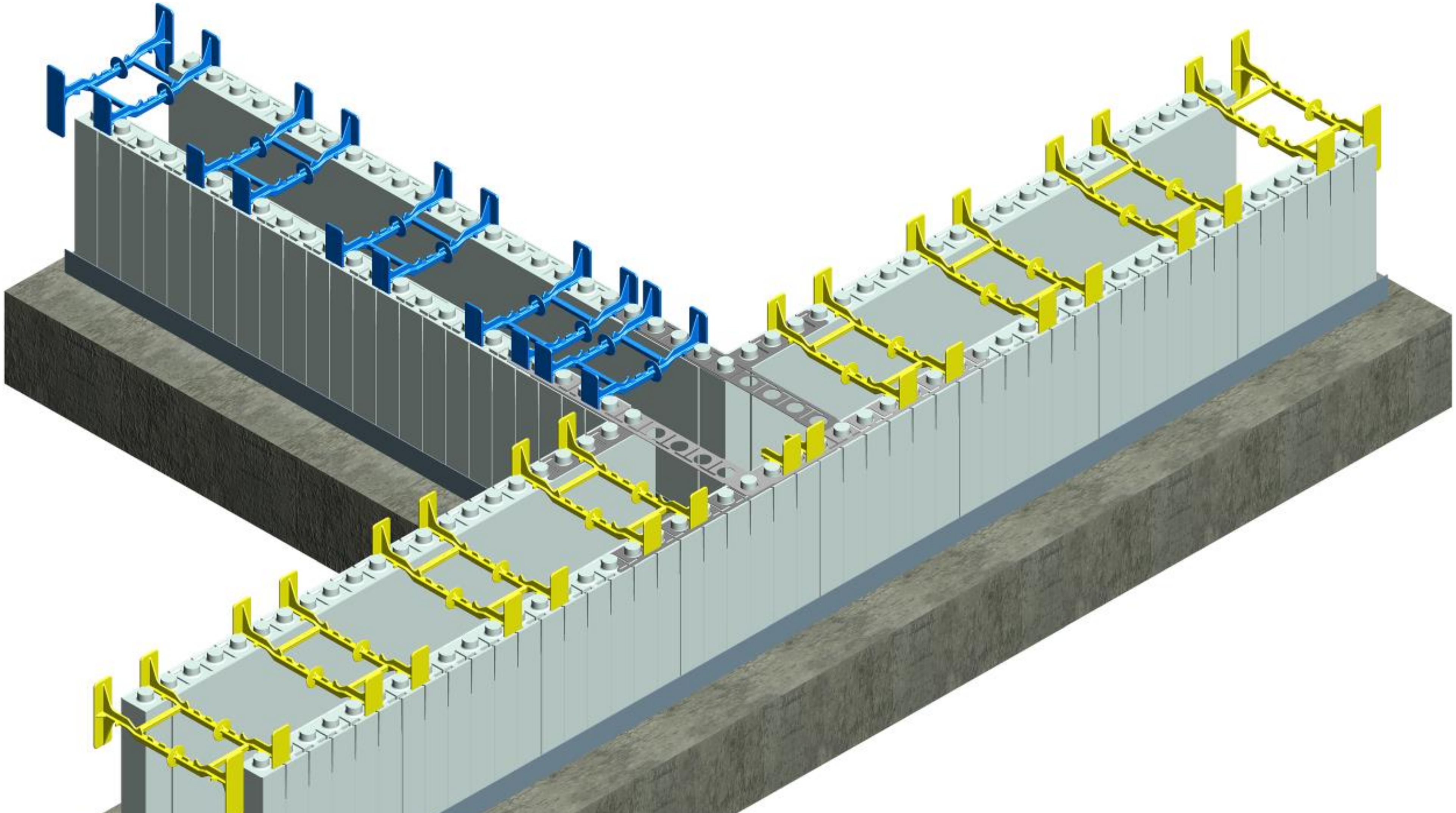
Improving ICF Window Installations

Improved ICF HP Window Installation

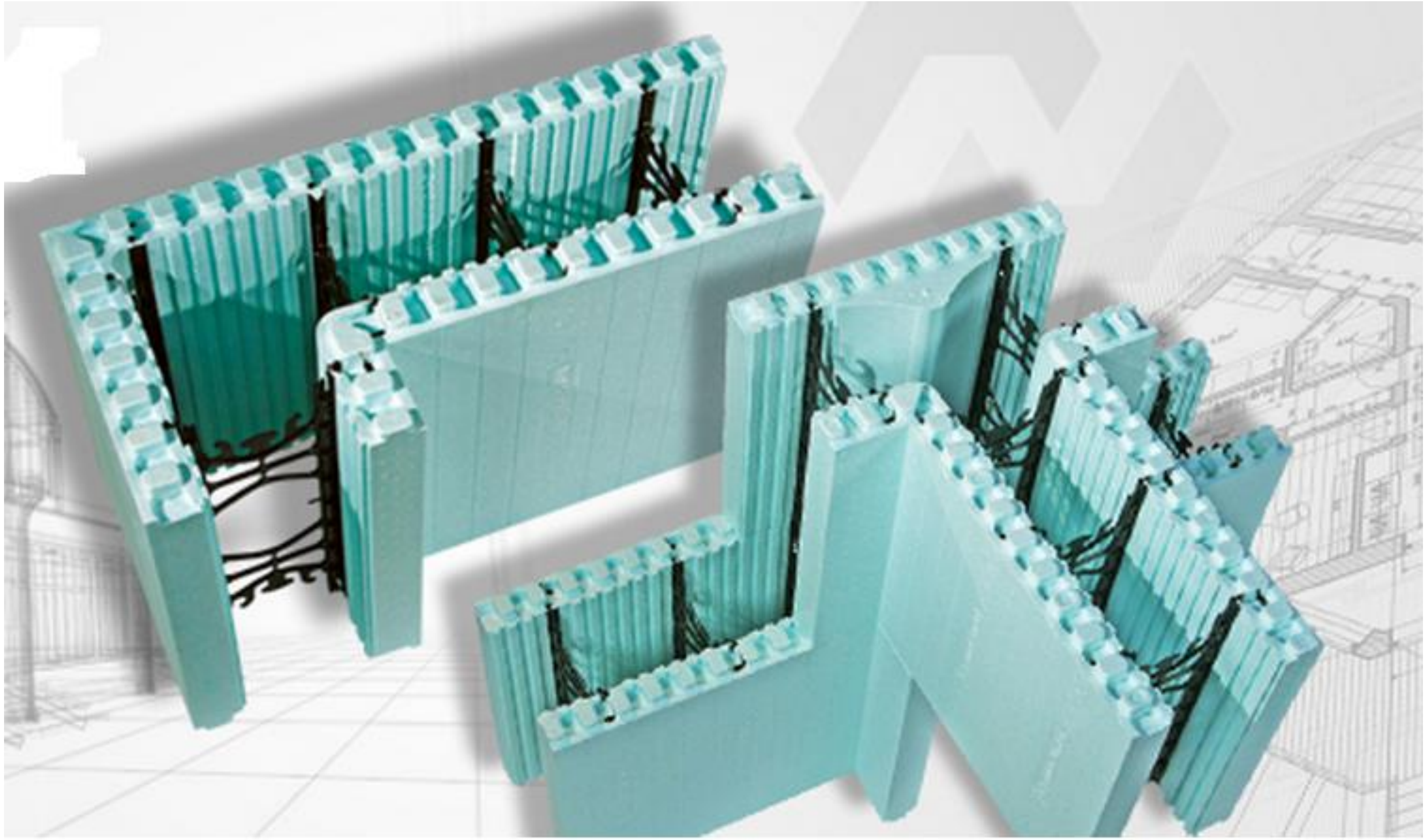
LBNL Therm 7 Infrared Image of ICF Foam Installation



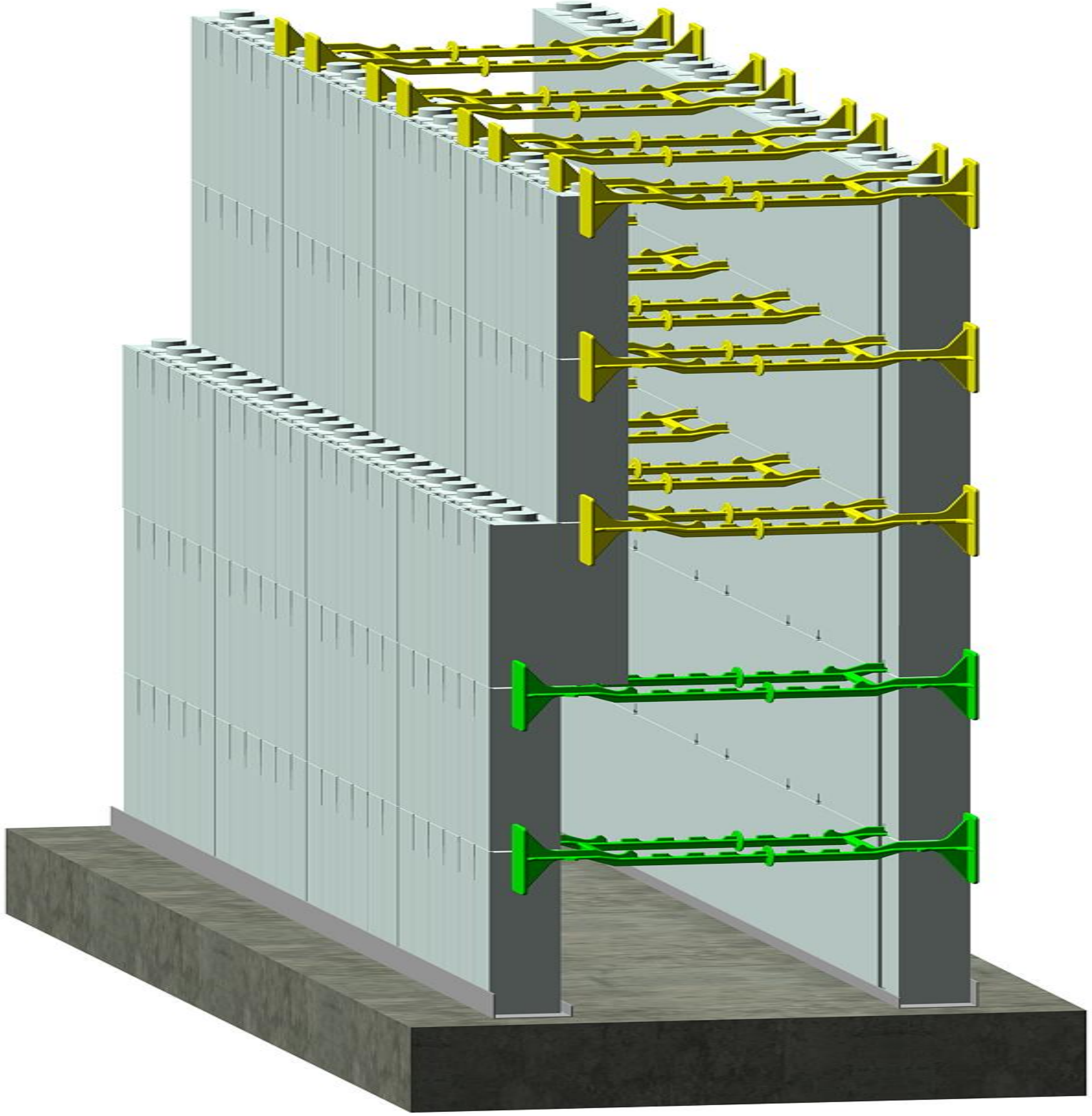
Quad-Lock T-Wall Connection



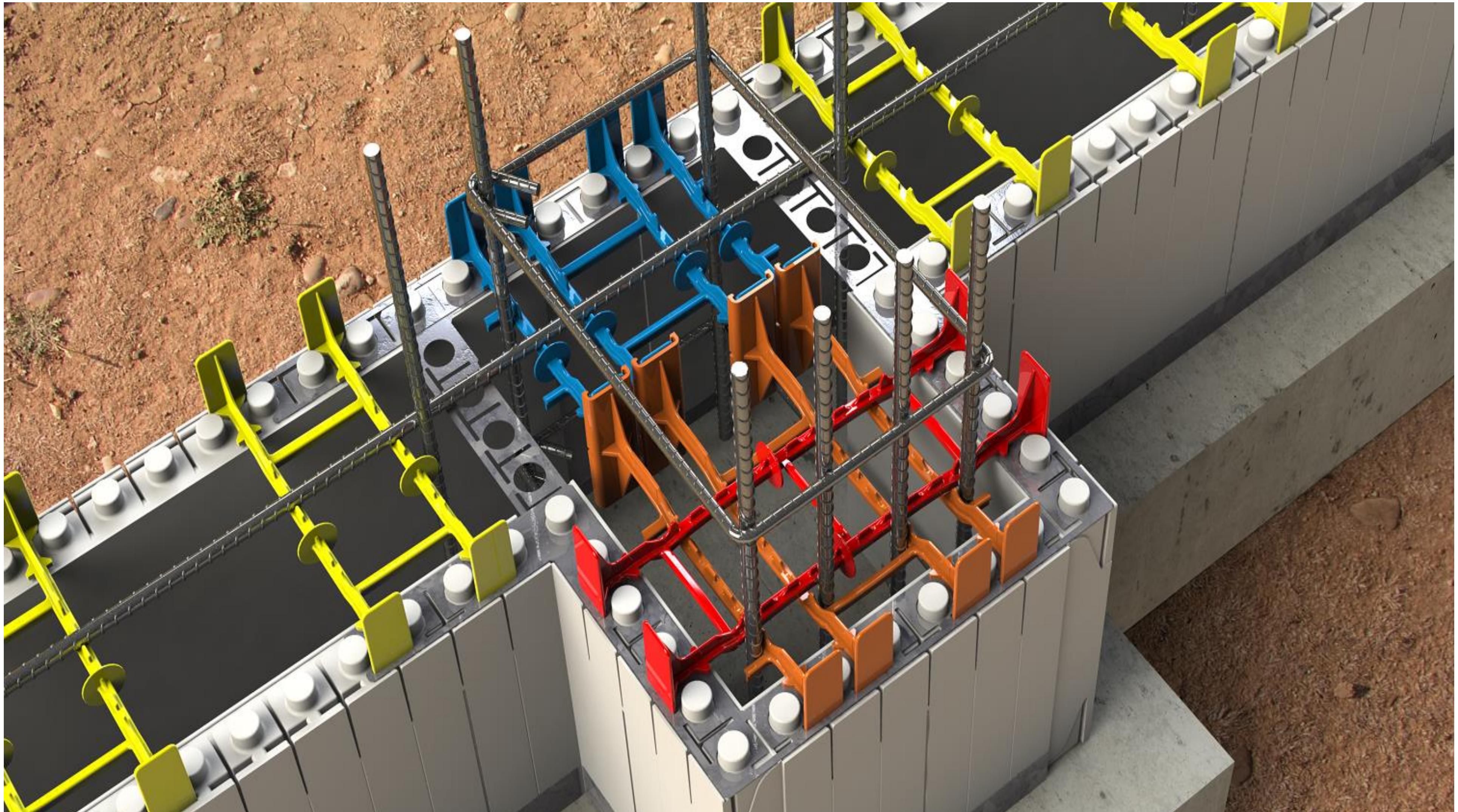
NUDURA ICF “Corner” & “T” Wall Forms



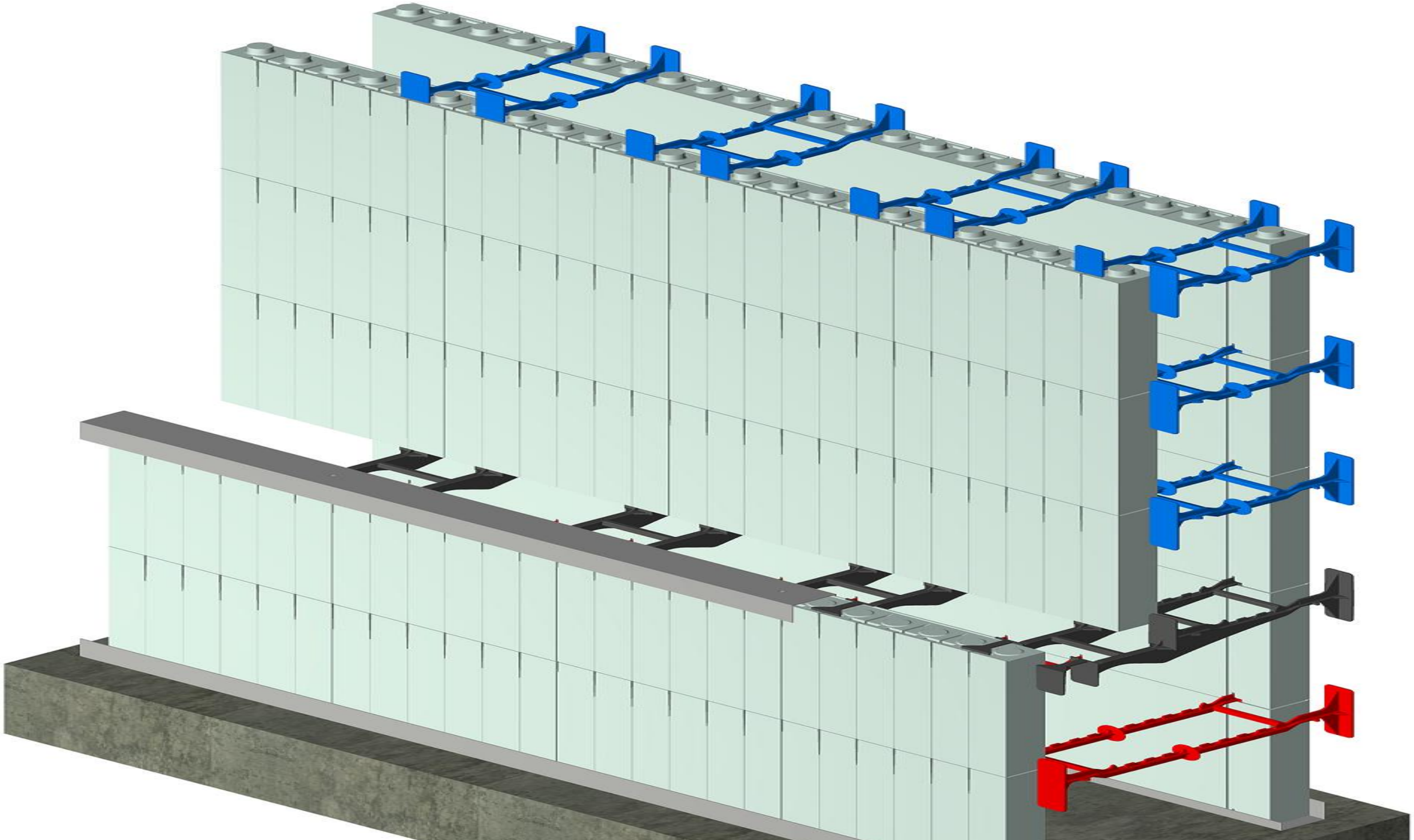
Quad-Lock Wall Width Transition



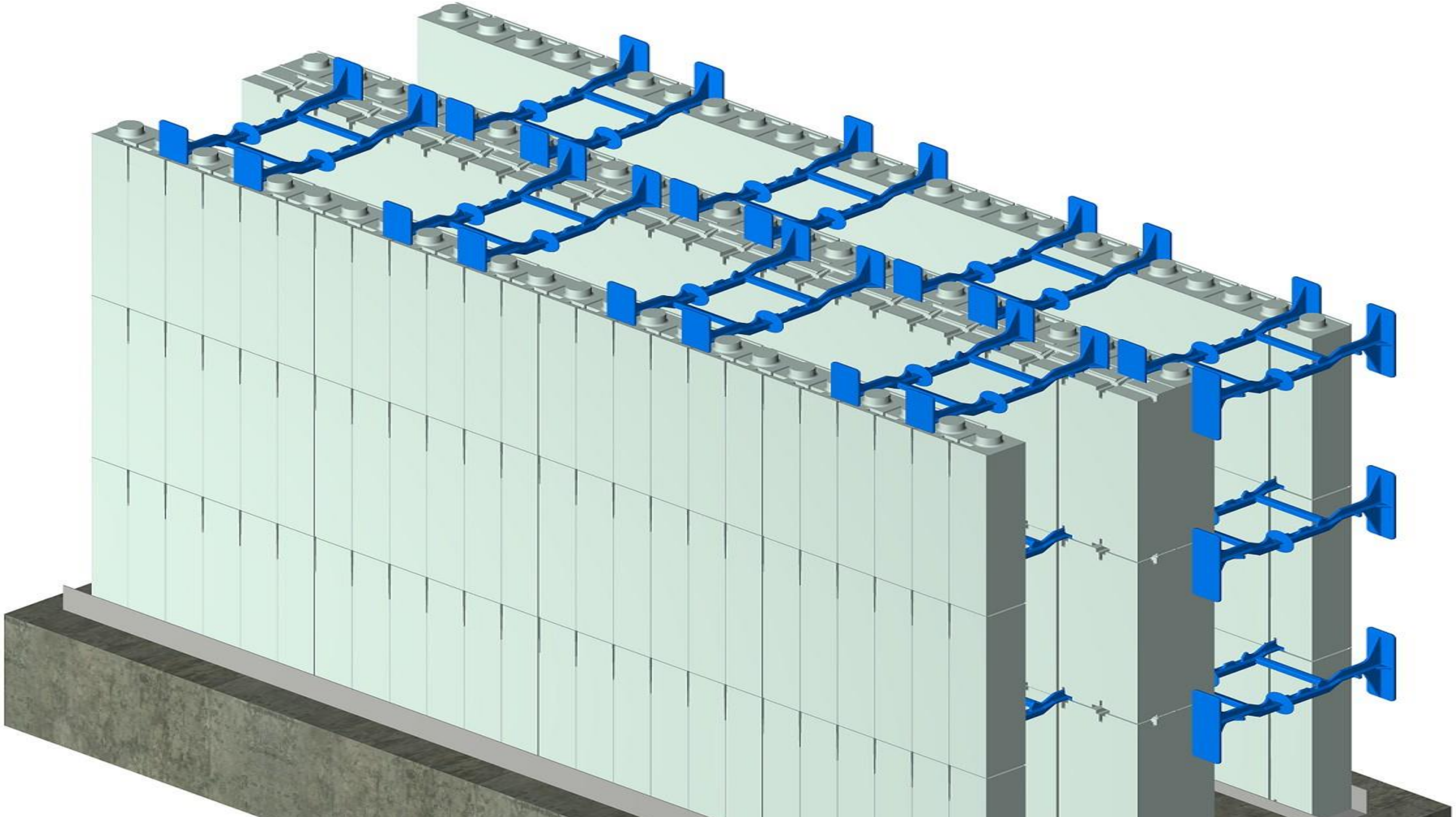
Quad-Lock Pilaster Configuration



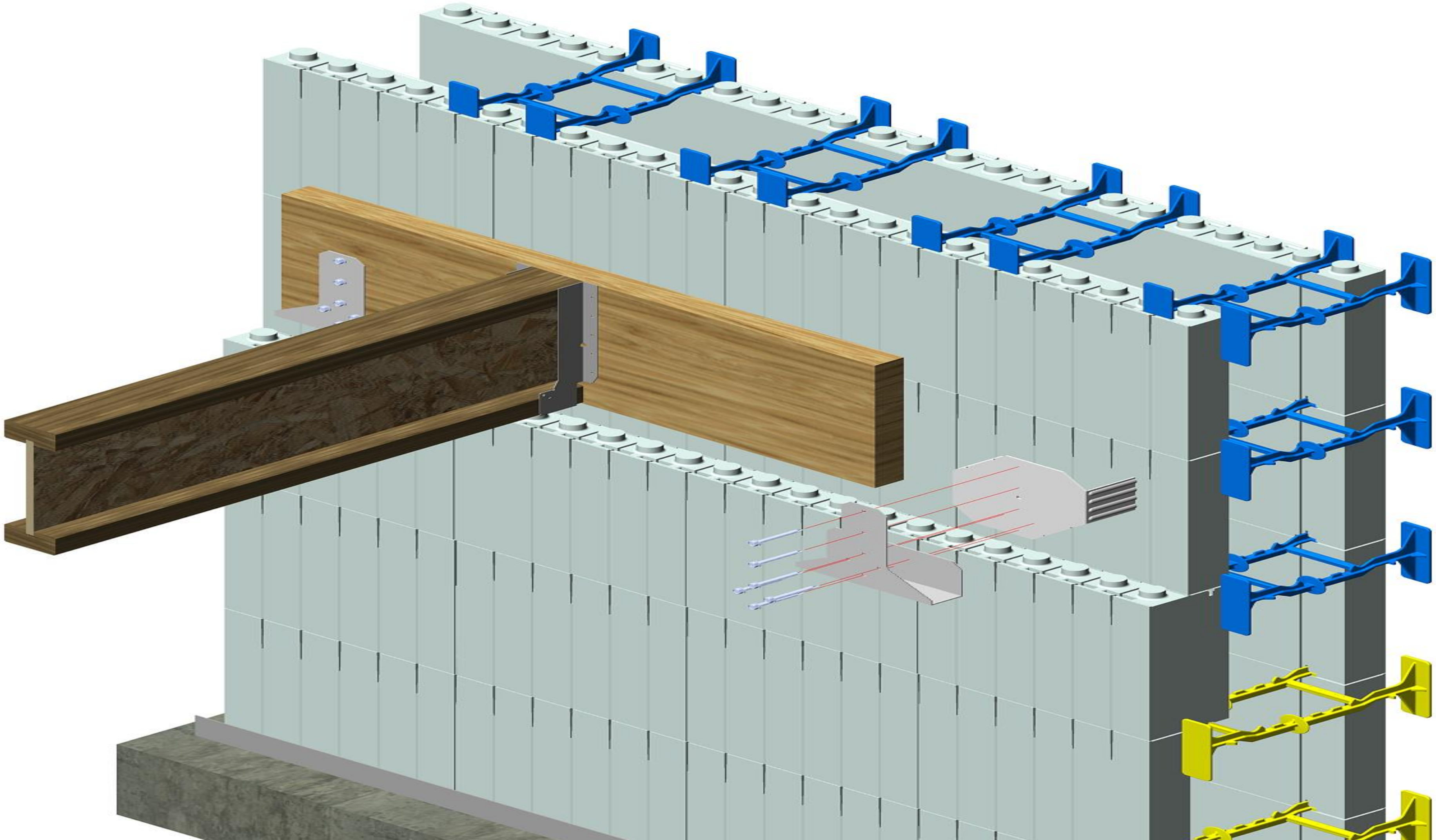
Quad-Lock Brick/Masonry Ledge



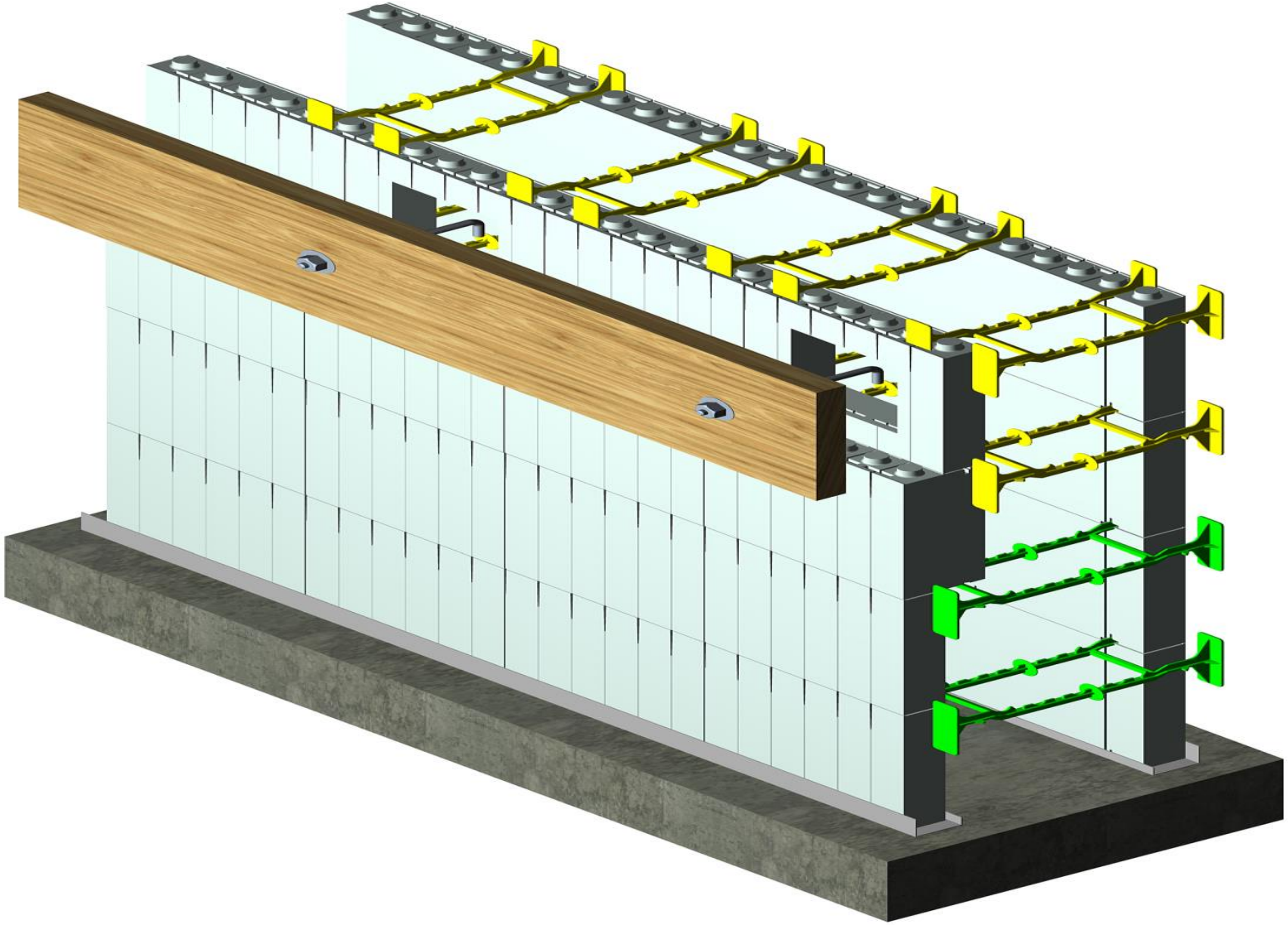
Quad-Lock Double/Common Wall



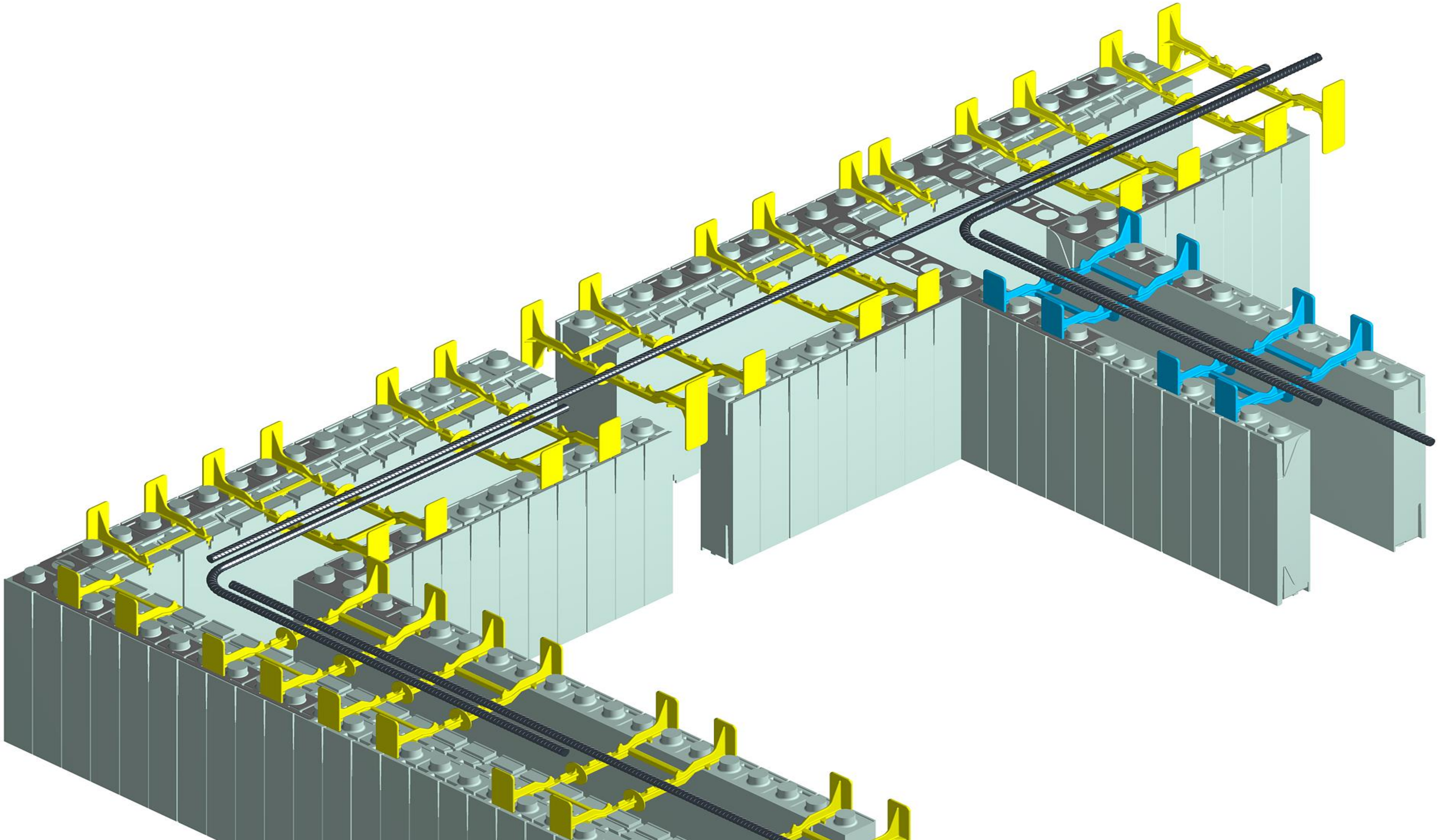
Quad-Lock Ledger Attachment
(Simpson ICF Ledger Connectors)



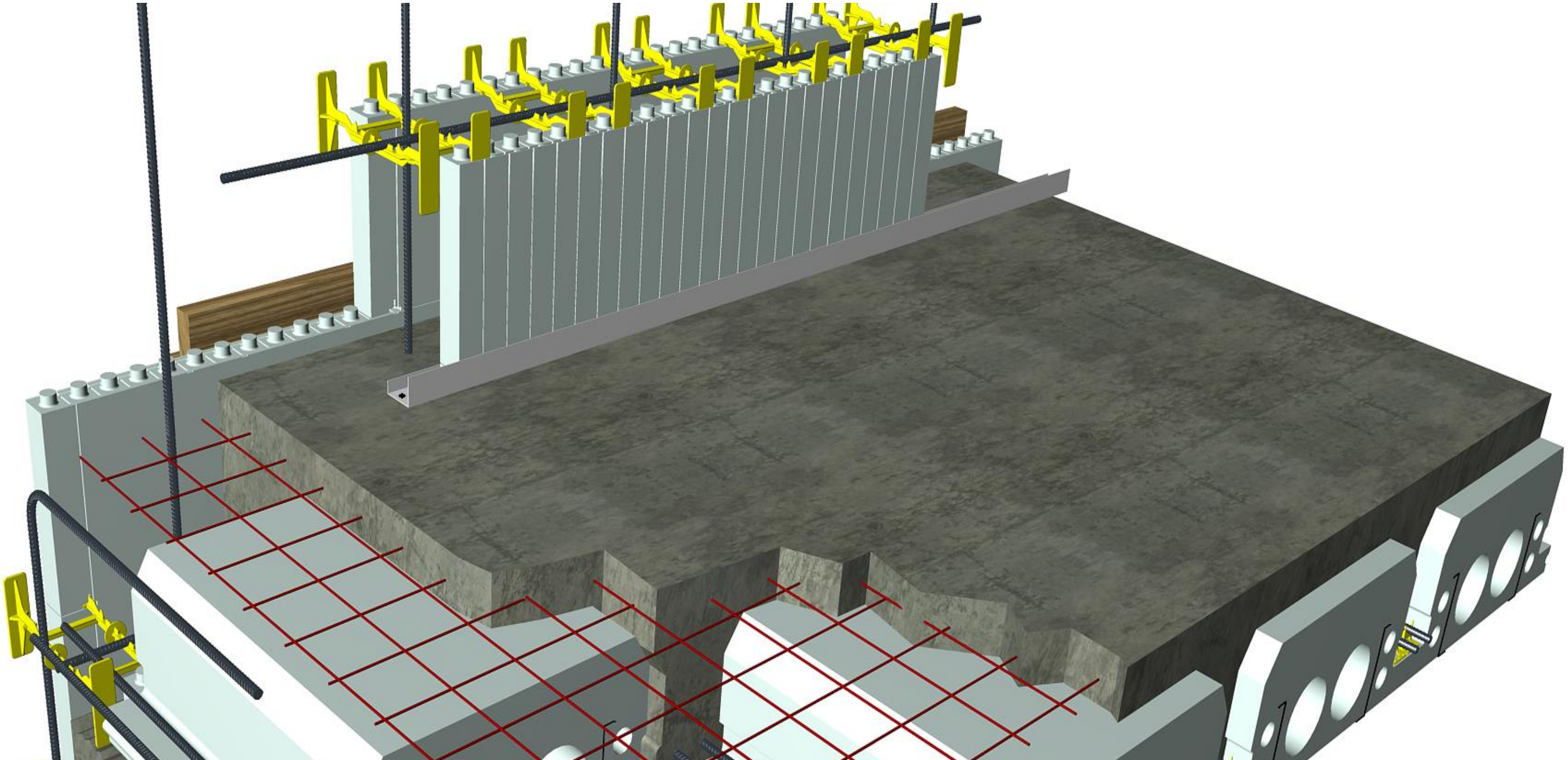
Quad-Lock Ledger Attachment
(Pre-Set Board with Bolts)



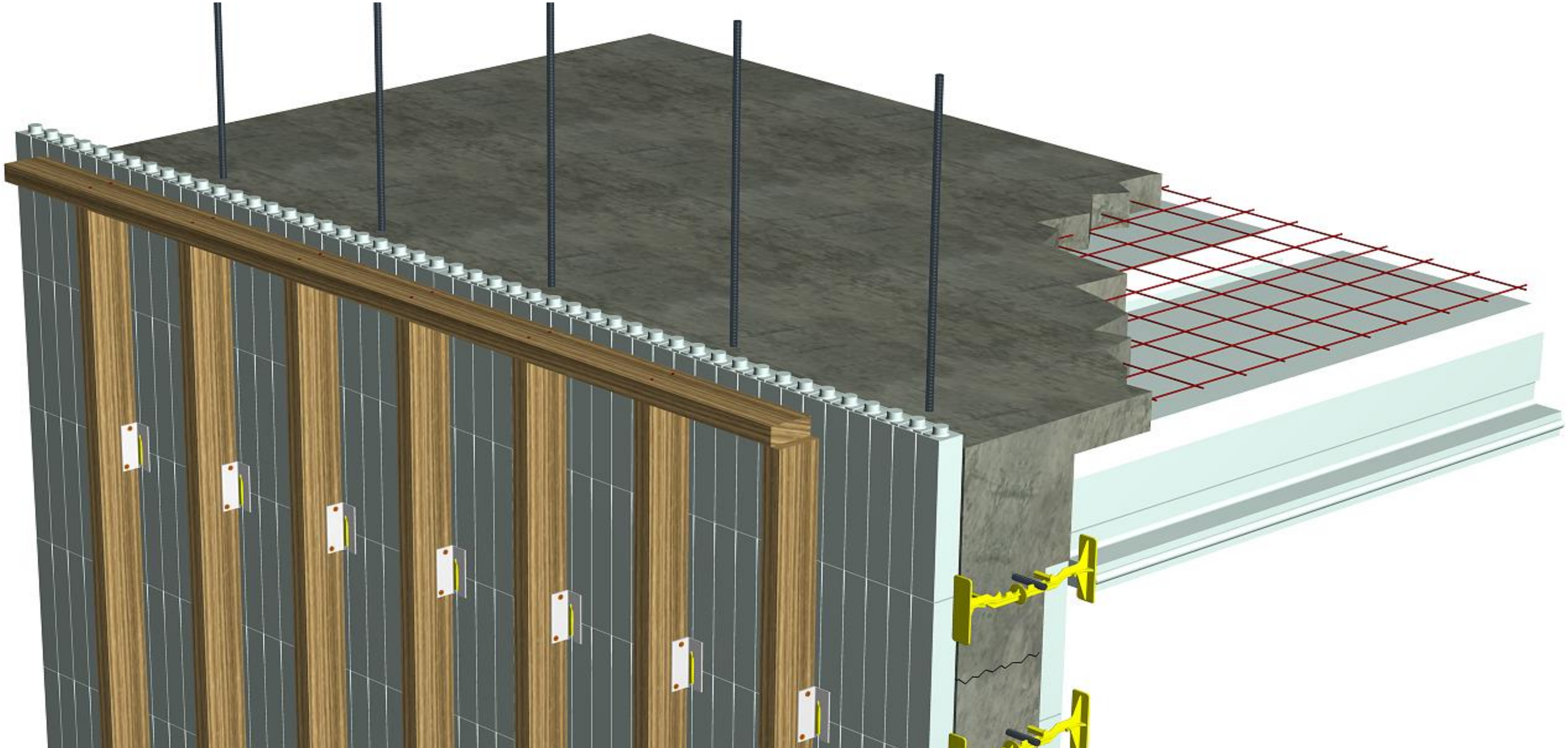
Quad-Lock Horizontal Rebar Placement



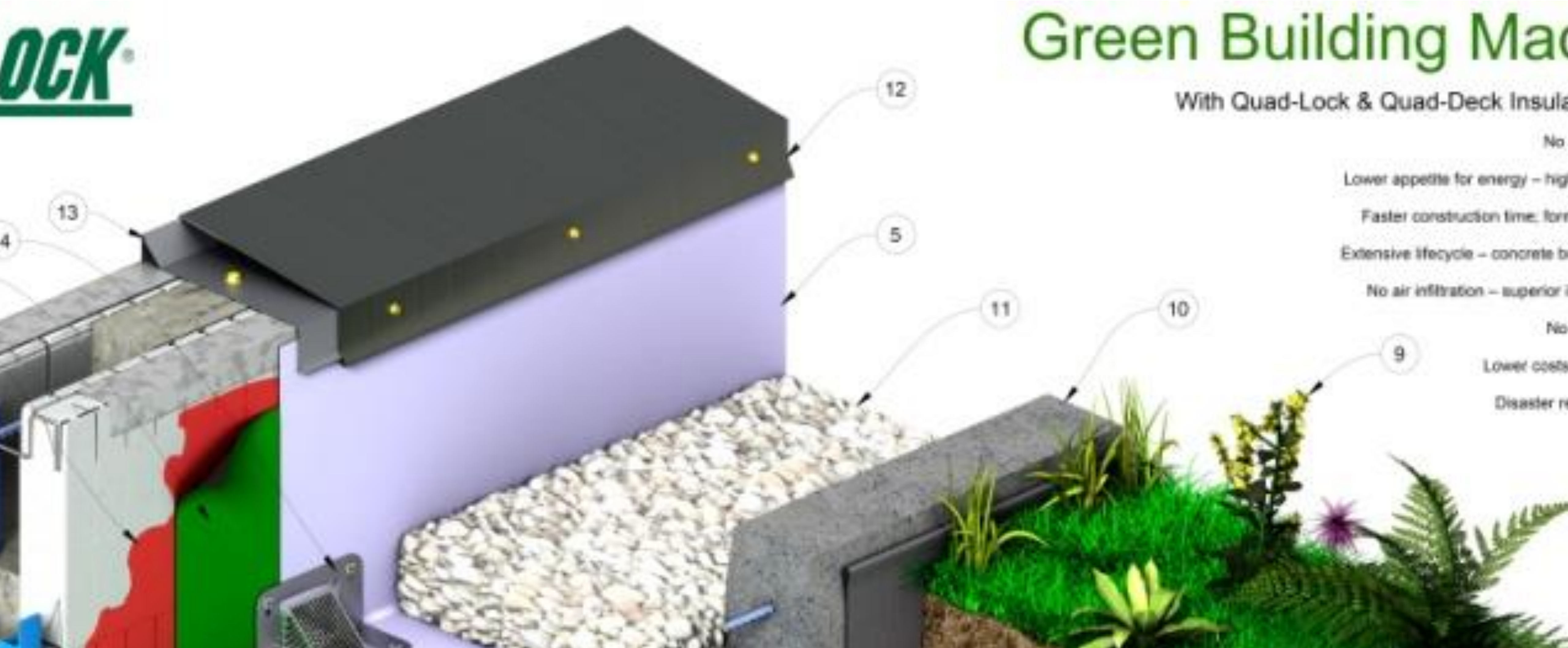
Quad-Lock to Quad Deck Connection & Slab Installation using Slab Ties



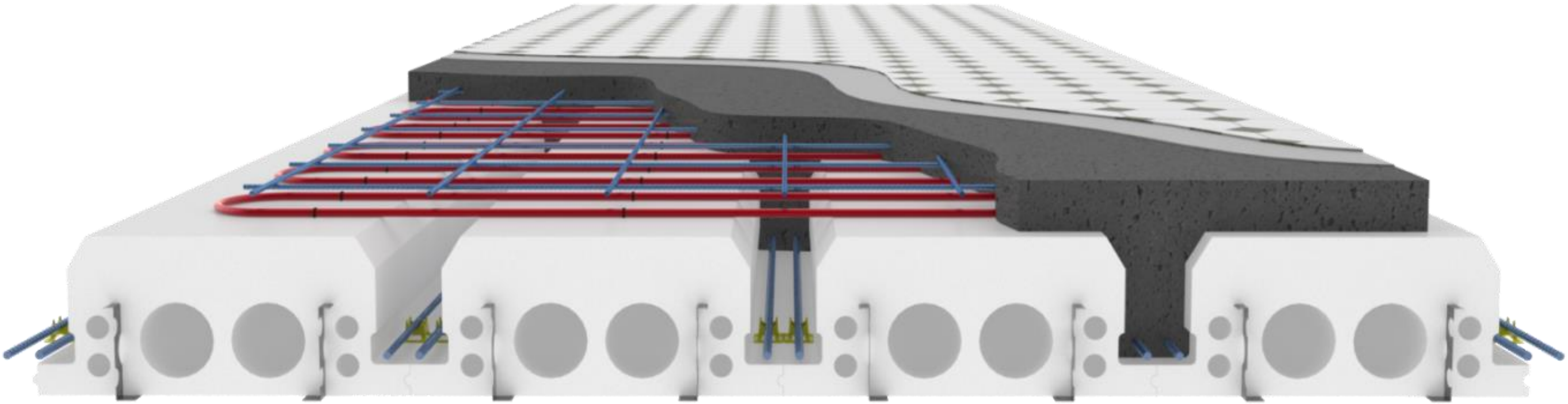
Quad-Lock to Quad Deck Connection & Slab Installation using Slab Ties



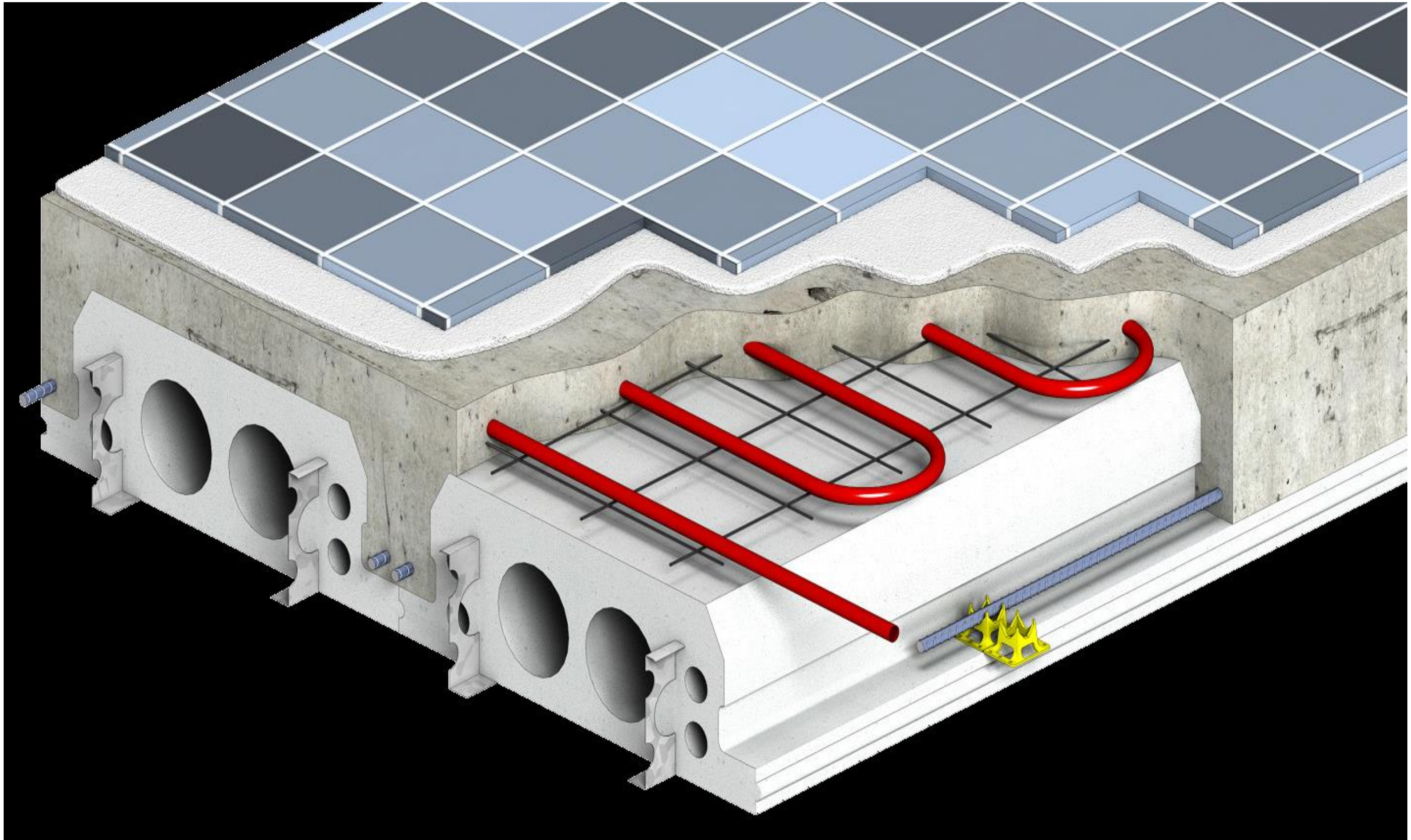
Integration of Quad-Lock Walls & Quad-Deck Flooring



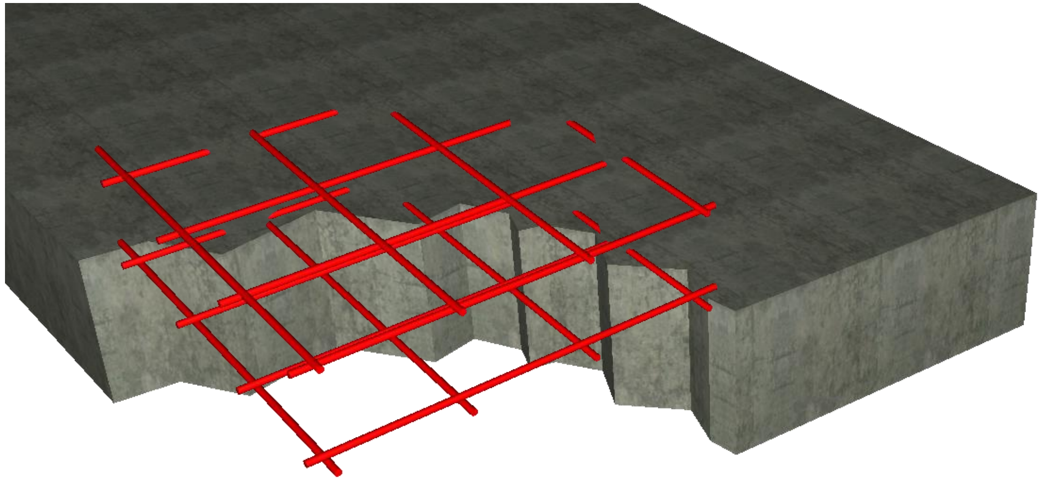
Insulated Quad-Deck T-beam Suspended Floor & Roof Systems



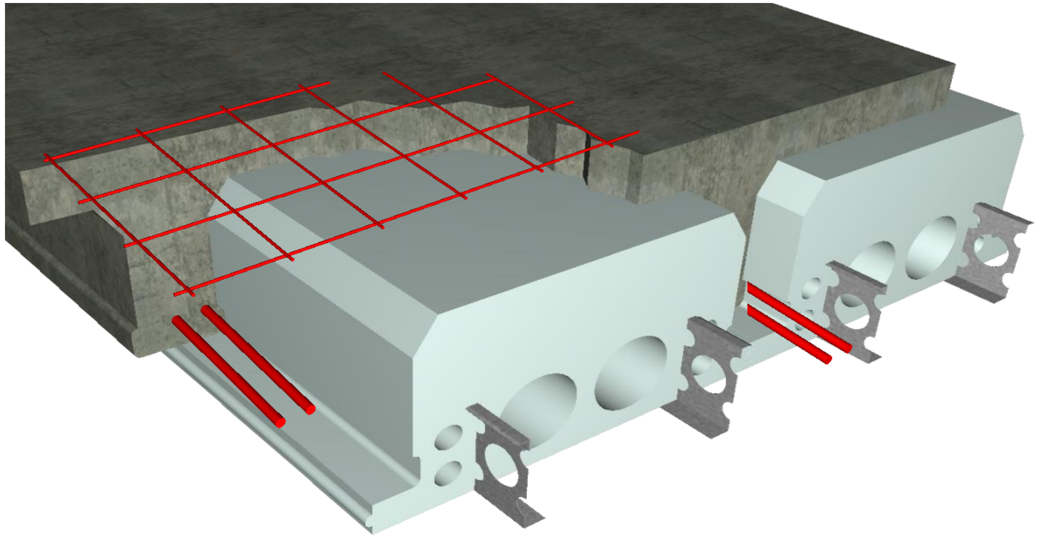
Quad-Deck Radiant Flooring



Concrete Slab vs. Quad-Deck
Concrete Requirements for 1500 sqft

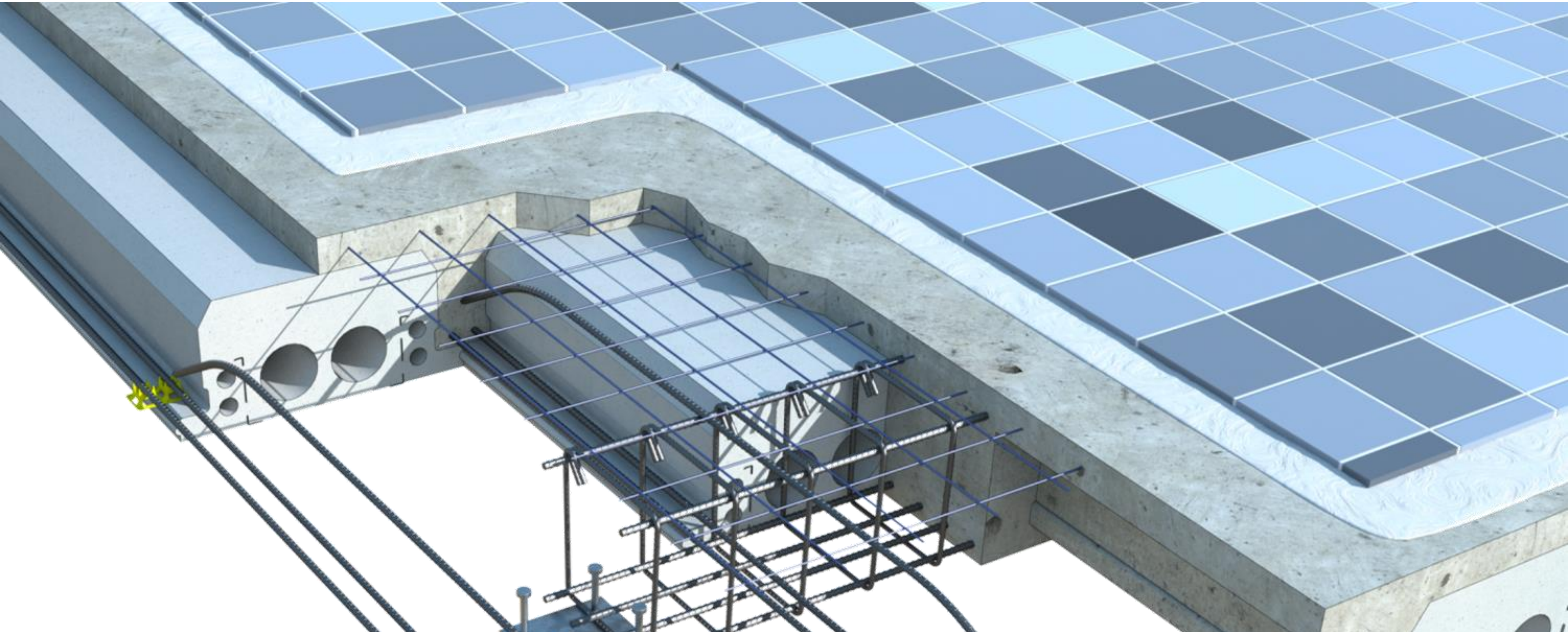


25'-0" Single Span: 8" Concrete Slab @ 50 psf LL		
Concrete needed		**37 cu. yd**
Top Reinforcement	#4 @12" O.C. E/W	1872 LB
Bottom Reinforcement	#6 @12" O.C. E/W	4209 LB
		6081LB



25'-0" Single Span: 11" QD + 2.5" Slab @ 50 psf LL		
Concrete needed		**18.4 cu. yd**
Top Reinforcement	6x6 WWM	288 LB
Bottom Reinforcement	2-#6 @ 24" O.C.	2883 LB
Quad-Deck Z-Strips	Spaced @ 12" O.C.	900 LB
		4071 LB

Extending Spans via Steel Reinforcing Posts & Post-tensioning of Quad-Deck System



Post-tensioning Concrete Slabs, Suspended Floors & Vaulted Ceilings

- Post-tensioning systems enhance economy, efficiency, quicker construction and lower lifetime cost of a structure. Post-Tensioning enhances concrete strength under both compressive and tensile stresses.
- For normal concrete, mix design allows for reaching 2,000 psi within 10-14 days after pouring before post-tensioning. In addition to increasing span lengths, this technology substantially reduces the volume of concrete required without compromising the strength of the concrete.
- For concrete mix designs comprised of 50% class F fly ash, that may require longer cure times to reach 2,000-3,000 psi for slabs and beams.
- Use of Class F fly ash and post-tensioning can be used for slabs, suspended floors, and vaulted ceilings to substantially reduce concrete, reinforced steel, and CO_2 emissions.

INSUL-DECK POST-TENSIONED FLOOR SYSTEM
SINGLE DIRECTION GENERAL NOTES
(Material Properties)

Post-Tensioned floor designs must be completed by a qualified, licensed, professional engineer and performed by a qualified, licensed subcontractor.
The tables listed in this estimating guide are based on the following material properties:

CONCRETE:

Compressive strength at time of tendon stressing:	fci'	=	3000	psi
Specified compressive strength:	fc'	=	4000	psi

MILD REINFORCING:

Specified yield strength:	fy	=	60,000	psi
Modulus of elasticity:	Es	=	29,000	ksi

POST-TENSIONING TENDONS:

Specified tensile strength:	fpu	=	270,000	psi
Approximated yield strength (0.85 x fpu):	fpy	=	229,500	psi

Shear Monolithic Connection between Beam and Slab

Eliminating 40% of the Weight of the Floor or Vaulted Ceiling

- Quad-Deck forms a one-way suspended slab design, where the joists only run in one direction, not two like a conventional concrete slab.
- This eliminates up to nearly half of the reinforcing steel, because the load is transferred mainly to two supporting elements (walls), not four. It also eliminates up to 40% of the weight of the floor or roof.
- This results in reducing the size of supporting elements while providing a structure with clear spans of over 30 feet supporting normal residential floor loads.

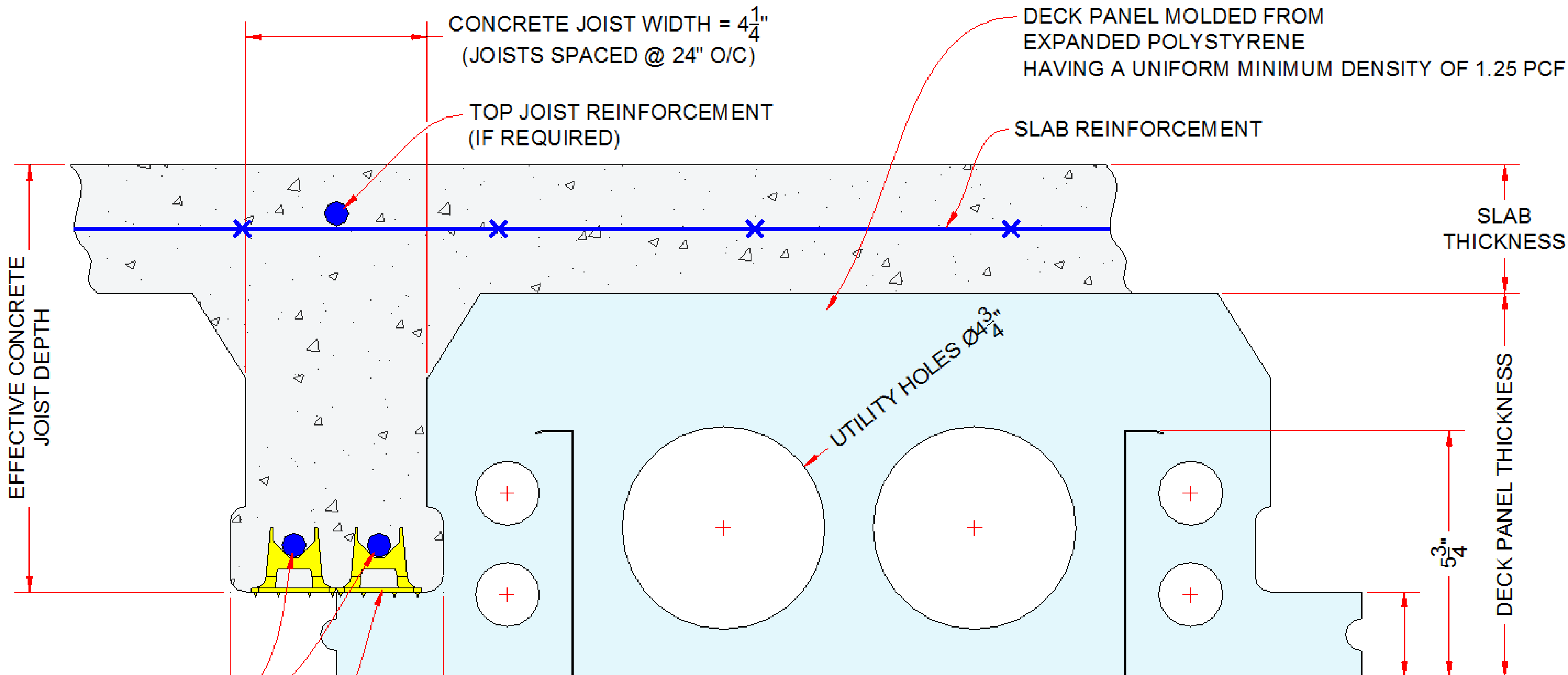
"Performance Based" Concrete Mix Design

- Compressive Strength
- Slump Characteristics
- Aggregate Size - 6" cavity
- Aggregate Size - 8" cavity
- Admixtures

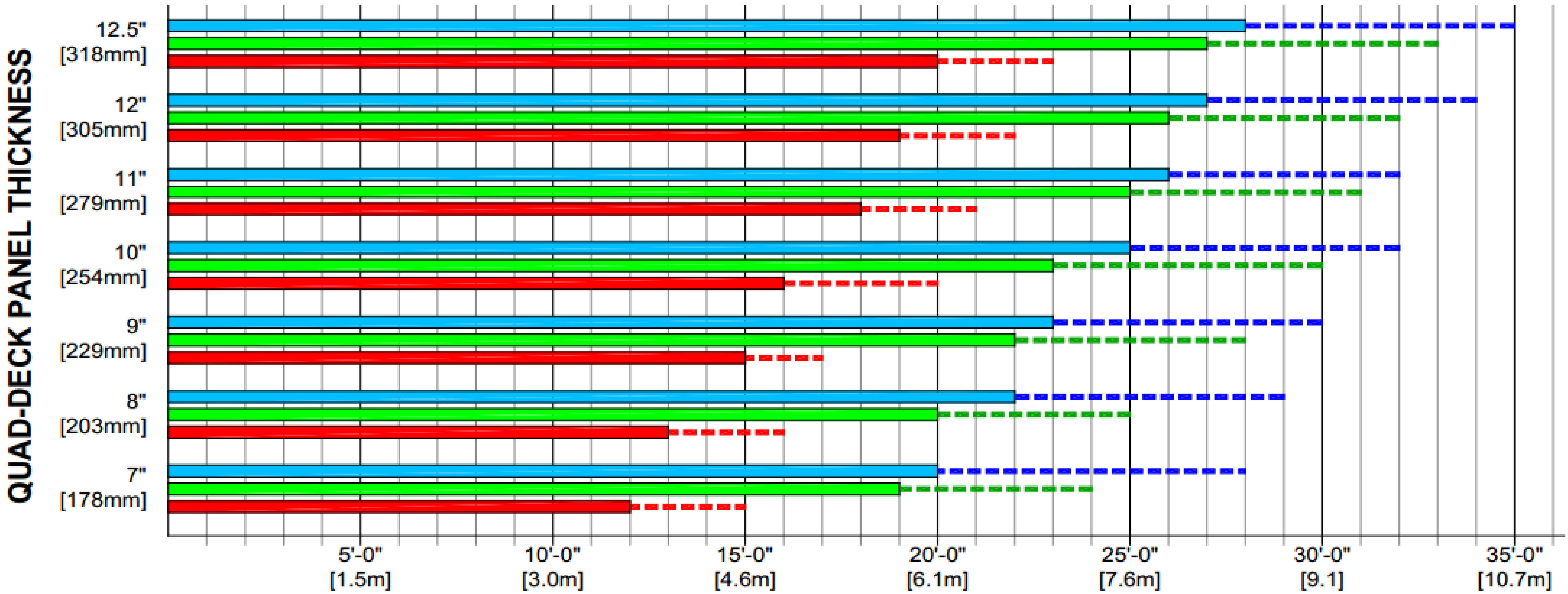
Examples:

- 3000 p.s.i. [23 Mpa]
- 6" [152mm]
- 3/8" to ½" [10mm -13mm]
- 3/8" to 3/4" [10mm -13mm]
- Plasticizer or other

Quad-Deck Panel Dimensions



QUAD-DECK SPANS (FOR ESTIMATING PURPOSES ONLY!)



CLEAR SPAN (Center to Center of Load Bearing Support)

LEGEND:

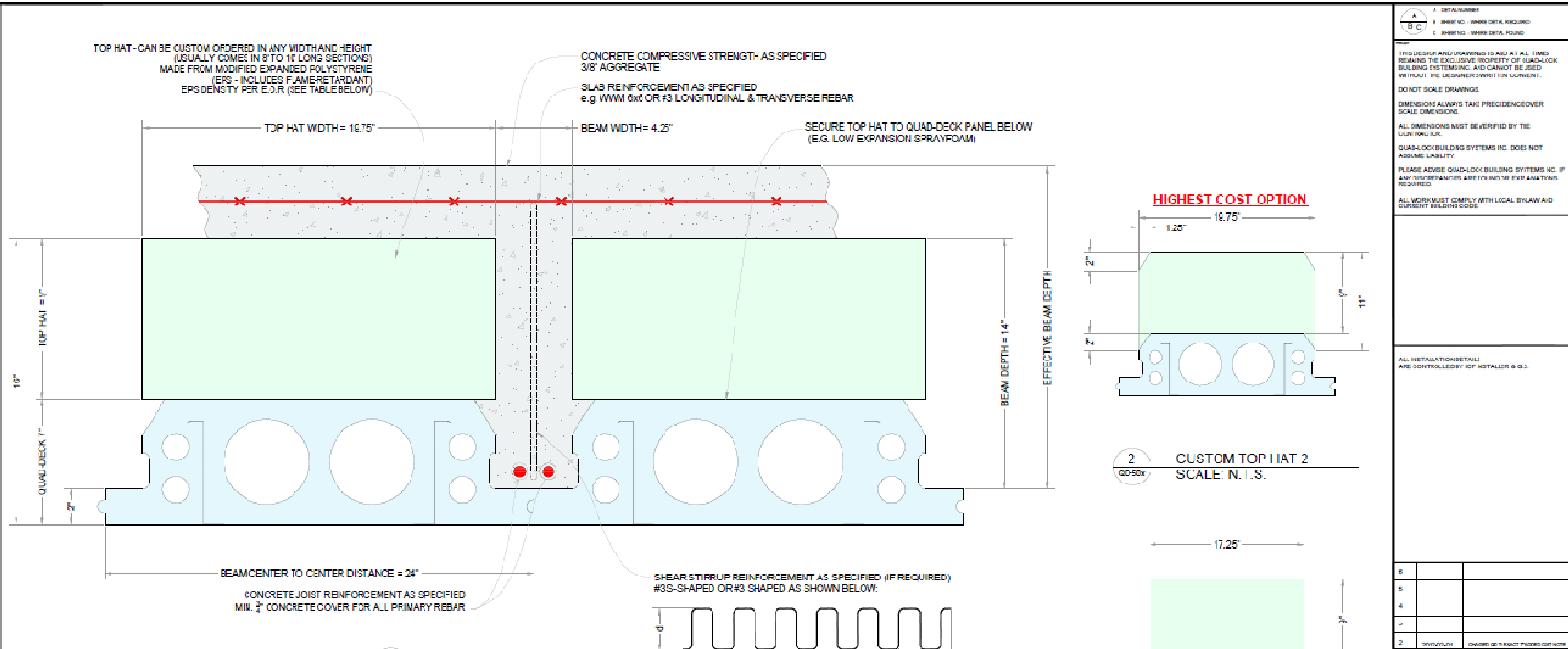
20 psf [0.95 kN/m²] Live Load, 3" [75mm] Slab Thickness, 3000 psi [21 mPa] Concrete, 2-#6 [2-20M] Rebar Bot.

40 psf [1.92 kN/m²] Live Load; 3" [75mm] Slab Thickness, 3000 psi [21 mPa] Concrete, 2-#6 [2-20M] Rebar Bot.

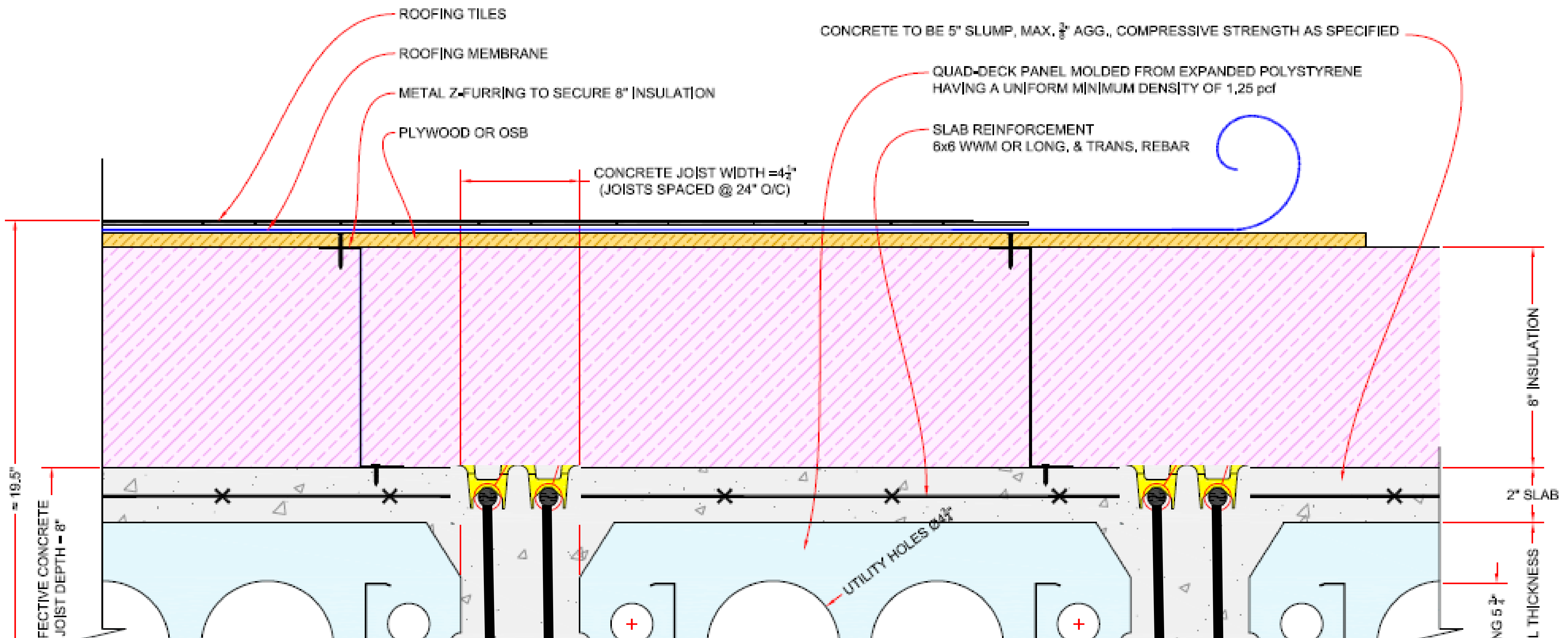
100 psf [4.77 kN/m²] Live Load; 3" [75mm] Slab Thickness, 3000 psi [21 mPa] Concrete, 1-#6 [1-20M] Rebar Bot.

4" [100mm] Slab Thickness, 4000 psi [28 mPa] Concrete, 2-#7 [2-22M] Rebar Bot. & 1-#6 [1-20M] Rebar Top

Quad-Deck Top Hat Design for 40’ Spans



Quad-Deck R-62 to R-74 Vaulted Ceiling Assembly



Cubic Yards of Concrete Mix per 1 sqft of floor

Quad-Deck Panel Thickness	Slab Thickness								
	2"	2.5"	3"	3.5"	4"	4.5"	5"	5.5"	6"
7"	0.009404	0.010948	0.012491	0.014034	0.015577	0.017121	0.018664	0.020207	0.021750
8"	0.009951	0.011494	0.013037	0.014581	0.016124	0.017667	0.019210	0.020754	0.022297
9"	0.010498	0.012041	0.013584	0.015127	0.016670	0.018214	0.019757	0.021300	0.022843
10"	0.011044	0.012587	0.014131	0.015674	0.017217	0.018760	0.020303	0.021847	0.023390
11"	0.011591	0.013134	0.014677	0.016220	0.017764	0.019307	0.020850	0.022393	0.023936
12"	0.012137	0.013680	0.015224	0.016767	0.018310	0.019853	0.021397	0.022940	0.024483
12.5"	0.012411	0.013954	0.015497	0.017040	0.018583	0.020127	0.021670	0.023213	0.024756

Notes:

This table is for estimating purposes only.

Example: a 3000sqft floor constructed with 10" Quad-Deck and 3" slab would require (3000 x 0.014131) = 42.4cuyd of concrete mix.

Surface Burning Characteristics - ASTM E84/ UL723

Flame Spread < 25; Smoke Developed < 450 (prior to floor ignition) per Preliminary Investigation Report by Underwriters Laboratory Inc. dated August 28, 2006.

Fire Resistance Ratings

Actual Fire Resistance Ratings shall be determined by the licensed professional engineer. The below Fire Resistance Ratings were estimated based on Table 2.1 "Fire resistance of singular layer concrete walls, floors and roofs" of ACI 216.1 and only consider the concrete slab thickness:

Aggregate Type	Quad-Deck Slab Thickness for Fire Resistance Rating (in)				
	1 hr	1.5 hr	2 hr	3 hr	4 hr
Siliceous	3.5" [89mm]	4.3" [109mm]	5.0" [127mm]	6.2" [157mm]	7.0" [178mm]
Carbonate	3.2" [81mm]	4.0" [102mm]	4.6" [117mm]	5.7" [145mm]	6.6" [168mm]
Semi-lightweight	2.7" [69mm]	3.3" [84mm]	3.8" [97mm]	4.6" [117mm]	5.4" [137mm]
Lightweight	2.5" [64mm]	3.1" [79mm]	3.6" [91mm]	4.4" [112mm]	5.1" [130mm]

Insulation Values - ASTM C578

Calculated as per ASTM C578, R-Value for Type VIII EPS is 3.8 per inch thickness @ 75°F. The ASHRAE Handbook allows using higher and more accurate R-Values for EPS, especially in cold conditions, in contrast to many other insulation materials that perform worse than advertised when heating or cooling is actually required. To determine the R-value of the concrete slab, concrete is about R-0.09 per inch thickness.

Quad-Deck Panel Thickness	7" [178mm]	8" [203mm]	9" [228mm]	10" [154mm]	11" [279mm]	12" [305mm]	12.5" [318mm]
Thermal Resistance R-Value (h•ft²•°F/BTU)	16	19	22	25	28	32	33
Heat Transfer Co-efficient U-Value (W/m²•K)	0.35	0.3	0.26	0.23	0.20	0.18	0.17

STC Sound Tests (Sound Transmission Loss - Airborne Noise) - ASTM E90

Per reports by Architectural Testing dated January 23, 2007, four tests were performed on different floor types as follows:

Floor Type	STC
12" [305mm] Floor Assembly (9" [228mm] Quad-Deck & 3" [75mm] Concrete)	46
12" [305mm] Floor Assembly (9" [228mm] Quad-Deck & 3" [75mm] Concrete) + 1 layer 5/8" [16mm] gypsum board	49
12" [305mm] Floor Assembly (9" [228mm] Quad-Deck & 3" [75mm] Concrete) + 1 layer 5/8" [16mm] gypsum board over resilient channel	50
12" [305mm] Floor Assembly (9" [228mm] Quad-Deck & 3" [75mm] Concrete) + 2 layers 5/8" [16mm] gypsum board	53

IIC Sound Tests (Impact Insulation Class - Field Test) - ASTM E1007-04

Per report by Southwest Research Institute dated October 06, 2008, four tests were performed on different floor types as follows:

Floor Type	FIIC
15" [381mm] Floor Assembly (12" [305mm] Quad-Deck & 3" [75mm] Concrete) - no finish on ceiling or floor	17
15" [381mm] Floor Assembly (12" [305mm] Quad-Deck & 3" [75mm] Concrete) - 2 Layers of 5/8" [16mm] Type X GWB ceiling finish	26
15" [381mm] Floor Assembly (12" [305mm] Quad-Deck & 3" [75mm] Concrete) - 1/2" [13mm] tile on floor and 1/2" [13mm] GWB ceiling finish	26
15" [381mm] Floor Assembly (12" [305mm] Quad-Deck & 3" [75mm] Concrete) - 5/8" [16mm] Jute Carpet on floor and 1/2" [13mm] GWB ceiling finish	70

Quad-Deck Floor Weights

Quad-Deck Floor Weights (lb/sqft)							
Quad-Deck Panel Thickness	**Slab Thickness**						
	2"	**2.5"**	**3"**	**3.5"**	**4"**	**4.5"**	**5"**
7"	45.1	51.4	57.6	63.9	70.1	76.4	82.6
8"	47.3	53.6	59.8	66.1	72.3	78.6	84.8
9"	49.5	55.8	62.0	68.3	74.5	80.8	87.0
10"	51.7	58.0	64.2	70.5	76.7	83.0	89.2
11"	53.9	60.2	66.4	72.7	78.9	85.2	91.4
12"	56.2	62.5	68.7	75.0	81.2	87.5	93.7
12.5"	57.3	63.5	69.8	76.0	82.3	88.5	94.8

Notes: *The above are unfactored estimated weights which include concrete (150pcf), reinforcement (3lb/sqft), Quad-Deck Panel (2lb/sqft) & misc. (2lb/sqft).*

Quad-Deck Floor Weights (Kg/m²)							
Quad-Deck Panel Thickness	**Slab Thickness**						
	50mm	**75mm**	**90mm**	**100mm**	**110mm**	**120mm**	**130mm**
178mm	218.8	278.8	314.8	338.8	362.8	386.8	410.8
203mm	229.6	289.6	325.6	349.6	373.6	397.6	421.6
228mm	240.4	300.4	336.4	360.4	384.4	408.4	432.4
254mm	251.2	311.2	347.2	371.2	395.2	419.2	443.2
279mm	262.0	322.0	358.0	382.0	406.0	430.0	454.0
305mm	272.8	332.8	368.8	392.8	416.8	440.8	464.8
318mm	278.2	338.2	374.2	398.2	422.2	446.2	470.2

Notes: *These are unfactored estimated weights which include concrete (2400Kg/m³), reinforcement (15Kg/m²), Quad-Deck Panel (10Kg/m²) & misc. (10Kg/m²).*

Integrated Metal Furring Joists

- 28 gauge steel Z strips contained in Quad-Lock panels provide structural strength and eliminate the need for secondary shoring members.
- 6’-8’ spacing of primary shoring is required and will support workers, steel reinforcement, and concrete.
- Quad-Lock panels are constructed to building specifications and delivered onsite ready for assembly.

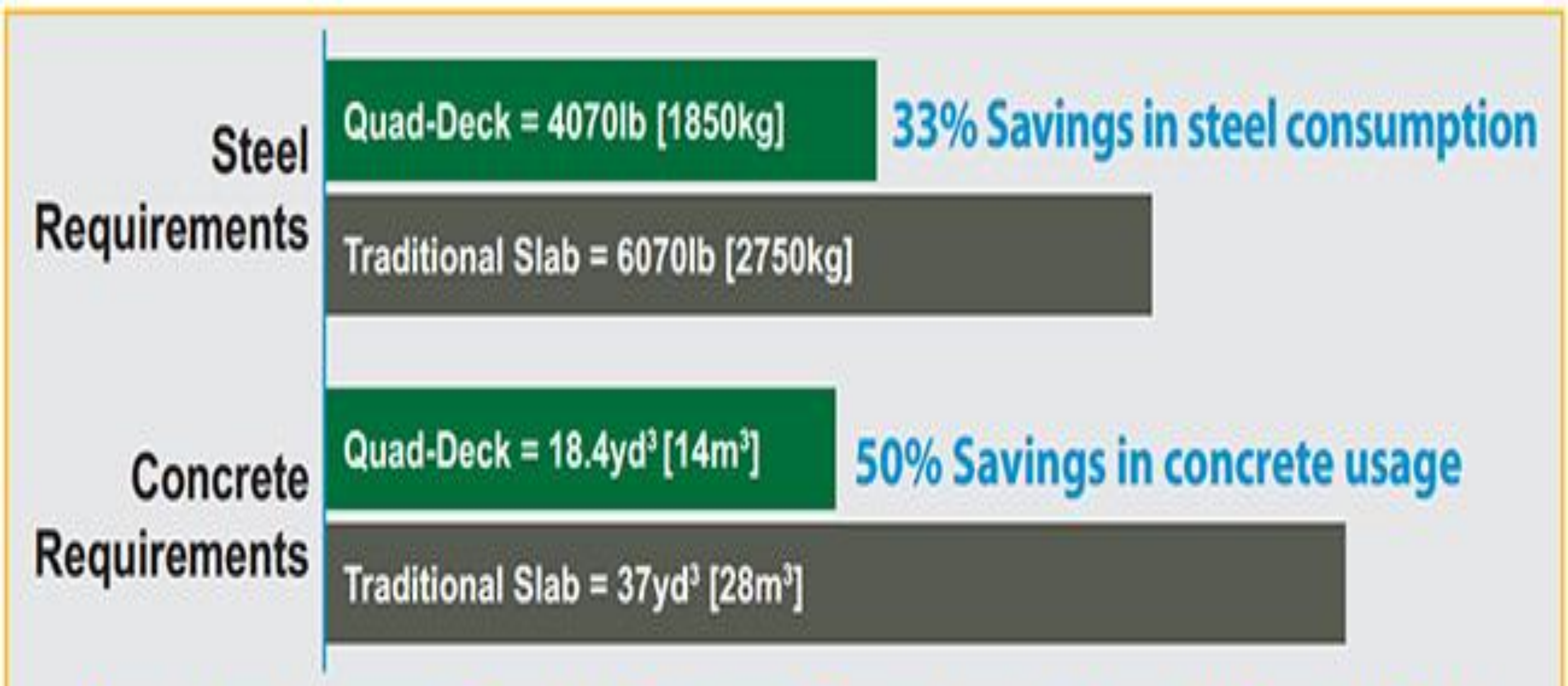
Quad-Deck Utility Holes

- Hollow cores in the Quad-Deck panels allow for running plumbing and electrical conduit/insulated wire through the ICF floor and ceiling structures using hot wire tools.
- The foam can be removed to install shared ducting for the ERV system and forced air cooling provided via integration with the geothermal heat pump.
- Quad-Deck panels allow for using up to 40% less concrete than full depth suspended slabs.

Interior ICF Bearing Walls

- The PHMH will include interior Quad-Lock walls for both the basement and main floor floors/ceiling structures which will limit need for shoring.
- Uniform sized logs and ICF block-outs will be utilized for supporting the Quad-Deck floor/ceiling structures and vaulted ceiling over the second floor during pouring/curing, and subsequently used for aesthetics.
- 9’ walls will accommodate up to 12” lodge logs or glue laminate beams used for floor/ceiling support.

Quad-Deck Economics



Energy Efficient Concrete Tile Roofing

- Locally produced concrete tile has become cost competitive with asphalt shingles while providing superior durability, performance, fire resistance, and curb appeal.
- A variety of colors and artisan/architectural styles are available to choose from depending on climate and geographical region with specific tile produced for harsh freeze-thaw environments.
- In most cases, when properly installed, concrete tiles can last indefinitely without requiring replacing.
- Raised battens provide the ability for air to circulate which virtually eliminates thermal transfer, thus substantially enhancing energy effieciency.

Bartile Concrete Roof Tiles

- **Durable:** 75 year Warranty, Exceeds Class A Fire Rating and Class 4 Hail Rating, Walkable, Made for Harsh Climates
- **Beautifully Custom:** Over 20 Styles and Options in over 700 Colors we can create any look you desire
- **Enviromentally Friendly:** Made of Recycled Material, Long Life Span, Made from Local Materials
- **Saves Money:** Insulates better to save on utility costs, One of the Lowest Lifetime Roofing Products
- Bartile provides standard for **custom colors and matchless styles**.

Legendary Slate - Flat Concrete Tile

Sierra Mission – Round Concrete Tile

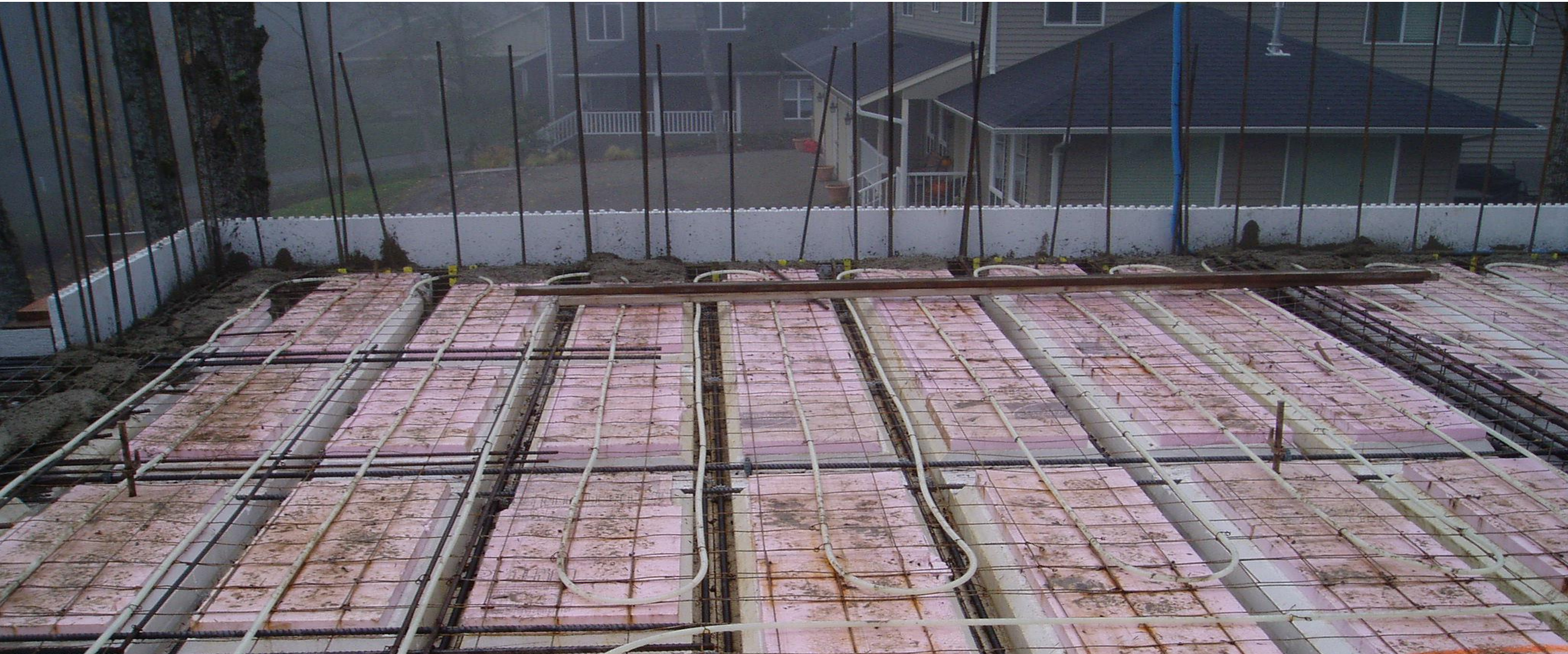
Radiant Concrete Floor & Solar Thermal

- Can be integrated with ICF and geothermal heat pump systems providing hot and cold water, and radiant floors in the PHMH.
- ERVs coupled with geothermal heat pumps and coils can also be used in addition to radiant technology to enhance air-flow and performance for the PHMH.

Sweat Equity

- Though commercial installation of radiant flooring can run $5-6 sqft, for ICF floors pex tubing can simply be tied to the concrete mesh prior to pouring.
- This allows for homeowners to actively participate in the construction process and dramatically reduce construction costs while providing the ultimate in comfort via radiant floor heating and cooling.

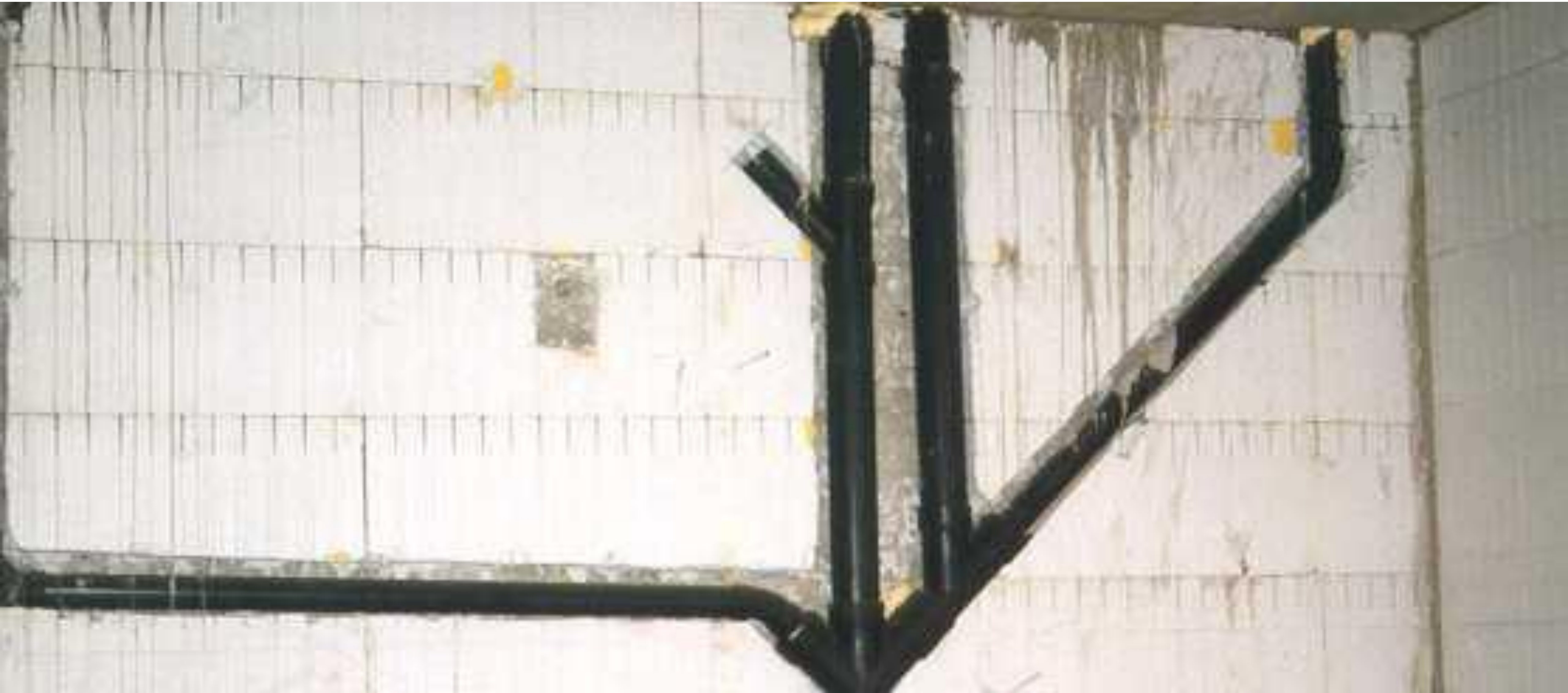
Radiant Heating & Cooling System inserted into ICF Quad-Deck Flooring



Radiant Heating & Cooling System Manifold to Geothermal Heat Pump

Electrical Conduit cut into Foam

Plumbing cut into Dense Foam



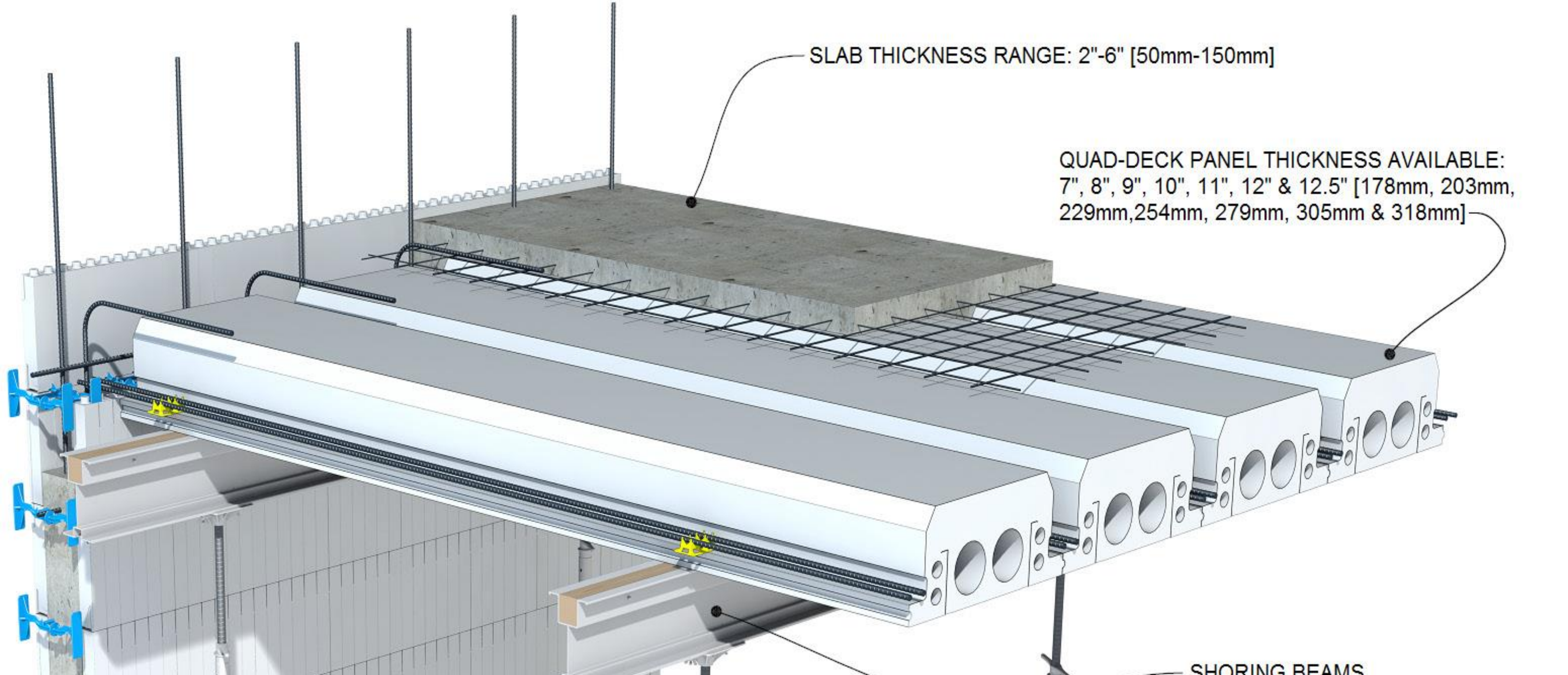
Quad-Deck Recessed Lighting Installation

Quad-Deck Recessed Lighting Installation cont.

Recessed lighting for pine decking finish would be installed prior to pouring Quad-Deck forms.

A hole would be cut out of the foam in which the recessed lighting would be inserted. The 5.25” utility holes would be used for running electrical wires.

Quad-Deck Ceiling Application

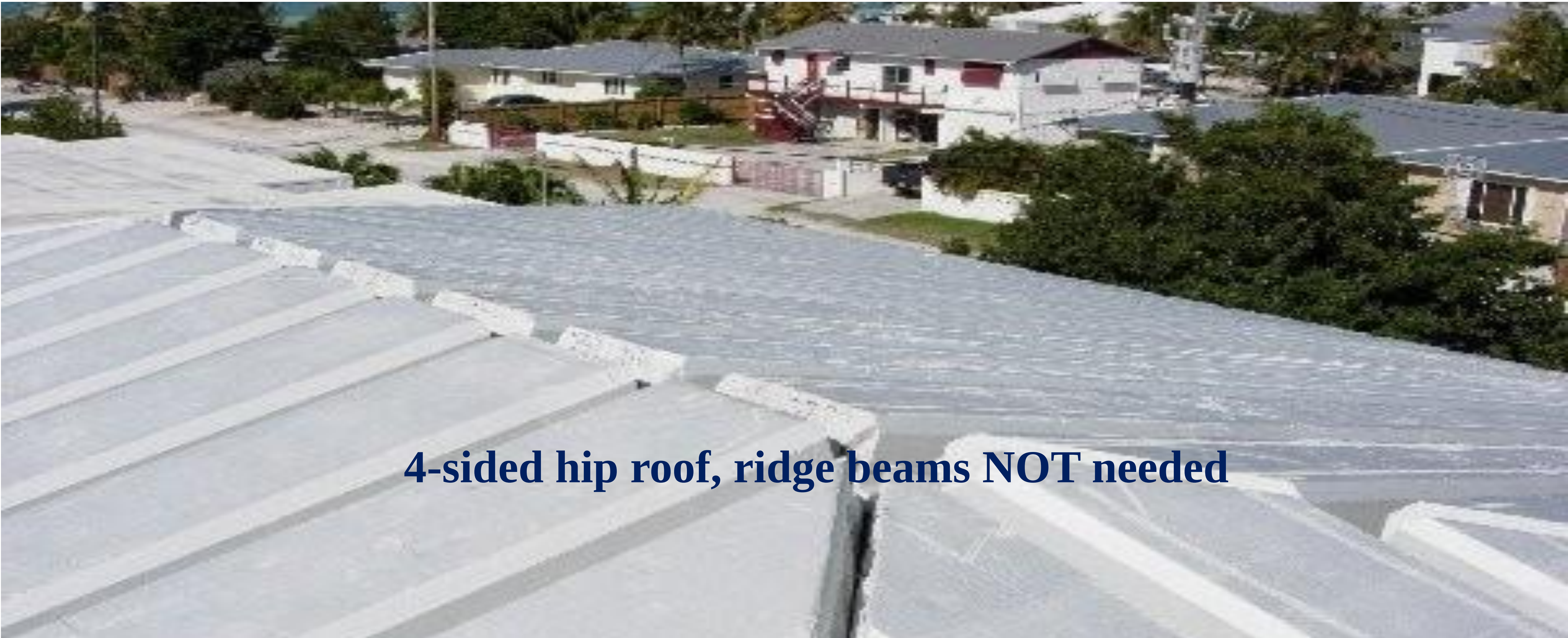


Reinforced Ridge Beams for Quad-Deck


12-18" Wide
24-30" High
Ridge Beam – up to 16" wide by 30" high

Quad-Deck Stair Opening

Pitched Roof for Vaulted Ceilings using Quad-Deck Panels



Quad-Deck Pitched Roof Ready to Pour

Quad-Deck Pitched Roof Pour Completed

Custom Manufacturing

- Quad-Deck panels are custom manufactured to size of spans according to building plans (4-sided hip roof, ridge beams NOT needed).
- The concrete roof will be covered with Foam-Control 16”x4’x8’ EPS (R-66) insulation plus ¾” OSB coverboard sheets glued and strapped to the concrete slab (covering the 8” R-16 ICF plus the 2-4” slab), providing a vaulted roof with a total insulation value of R-80 and no thermal bridging (27-29” thick vaulted roof).
- The roofing membrane will then be attached to the OSB coverboard.

Foam-Control EPS Boards

- 20 year warranted stable R-value: no thermal drift
- Unlimited fabrication available: Tapered and Coverboards
- Variety of density, thickness, and size
- Meets ASTM C578
- Building code recognized
- UL QA monitored, tested, certified, listed
- FM Approved
- Single-Ply, MOD-BIT, and BUR compatible
- Shingles including solar shingles can be attached directly to the OSB nail base

Advantages of Quad-Deck

- Quiet, Healthy, Safe & Comfortable
- More consistent indoor temperatures
- High STC ratings; deadens sound transmission
- Minimized air infiltration - fewer allergens, improved indoor air quality
- Inert materials: doesn’t support the growth of mold or mildew
- Rated Fire Resistance (using ACI 216.1)
- Not a food source for insects
- Superior protection against disasters

Durable & Sustainable

- High R_{ip}-Values (R-16 to R-33.5); Low U_{si}-Values (0.35 to 0.17)
- Reduced HVAC requirements, heating and cooling costs
- Thermal mass properties; ideal for passive solar designs
- Lower life-cycle costs
- Long-term building durability; life-cycle measured in centuries

Fast & Flexible

- Lightweight, easy to handle - no forms to be stripped
- Delivered to site ready to install - pre-cut at factory to exact specifications
- Self-reinforced forms - temporary shoring only every 6'
- Available in thicknesses of 7" to 12½", up to 34' [10.3m] free spans (and more with additional EPS caps or post-tensioning)
- Slab thickness from 1¾" to 6" [45mm to 152mm]
- Easily integrates with Quad-Lock ICF system

Lightweight

- Lighter structure; eliminates 50% of conventional shoring
- Reduces floor mass dead load by up to 50%
- Reduces structural requirements for foundations and walls

Reduced Costs

- No site waste
- Uses less concrete & steel compared to traditional concrete slab
- Lower workers-comp due to lightweight forms

Quad-Lock to Quad-Deck Connection

Quad-Lock to Quad-Deck Connection cont.

Quad-Deck Crossbeam

Quad-Deck Pour

Quad-Lock & Quad-Deck Installed

Quad-Lock ICF Structure

Stronger Concrete Structures

- Water does not evaporate as quickly from Quad-Lock in comparison with other ICF systems.
- This higher moisture content during curing results in a 50-70% increase in compressive strength (e.g., 5,700 lb/in^2 vs. 3,600 lb/in^2 for conventional plywood concrete forms).
- Removal of bracing can occur about 48-72 hours after pour.
- 80% curing is required before backfilling.

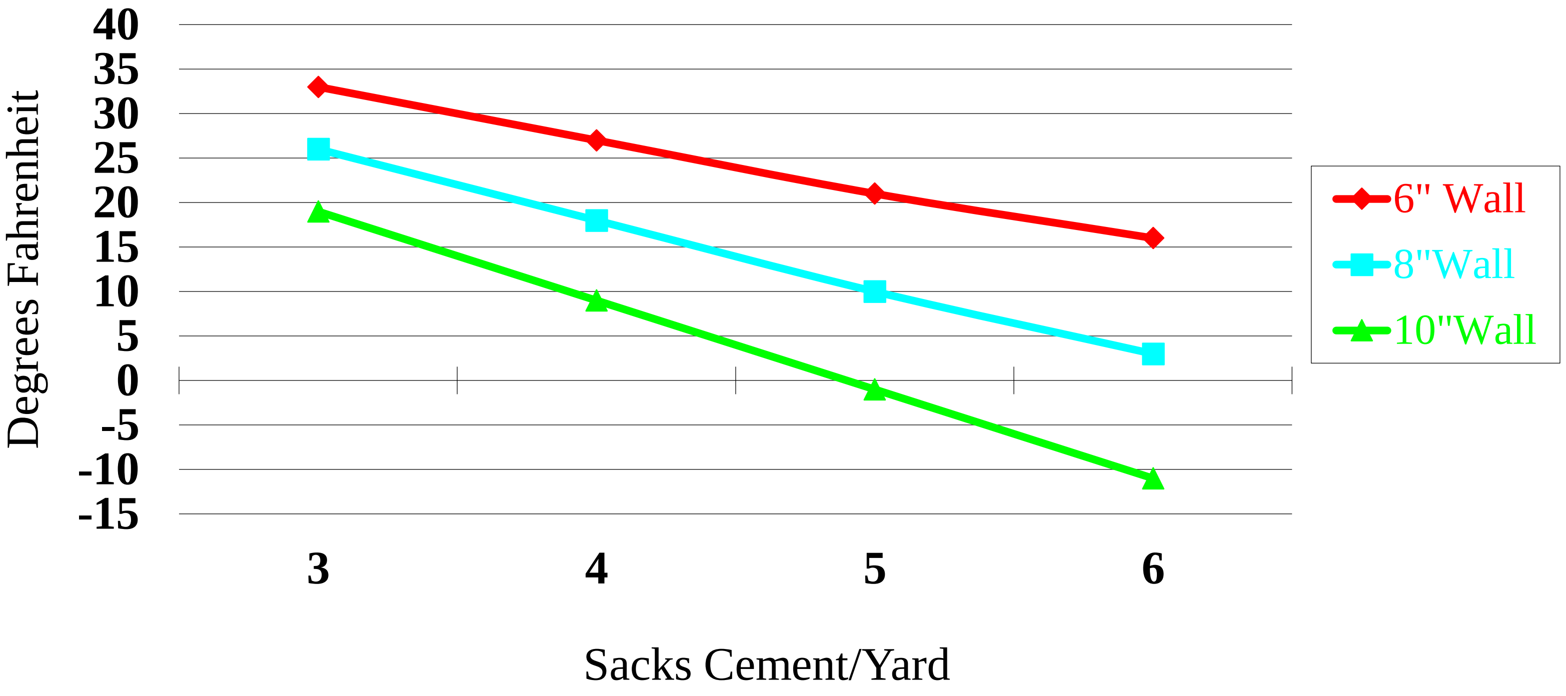
Fly Ash & Blast Slag

- Relatively high percentages of fly ash and blast slag will be utilized for substituting cement in Quad-Lock ICF.
- Addition of these substances will affect slump, cure time, and initial compressive strength and thus will be taken into account.
- Use of Pozzolans to concrete mix generally makes the mix more flowable which is advantageous for ICF construction. However, this may affect the dosage of plasticizers or other agents used to improve flow characteristics and care must be taken not to exceed recommended 6” slump.
- Engineers will take this into consideration.

Cold Weather Pouring

- Quad-Lock Plus panels allow for pouring with temperatures as low as -75° F.
- This is achieved by placing concrete and maintaining surface temperature at 50° F for 3 days.
- This is possible by increasing EPS insulation (R-59 Quad-Lock Plus panels) and by increasing cement content to 600 lb/yd^3.

Per ACI 306 R-88, ICF forms insulated to R-9.4 each side can be poured at the following minimum ambient temperatures and cement contents and maintain the concrete at 50°F for 3 days with high early concrete.



Cold Weather Curing

- Concrete must arrive at the site sufficiently warm to be placed at or above certain minimum temperatures according to Quad-Lock ICF configuration and cement content.
- Air entrainment should be included in the mix design if concrete is being exposed to freezing temperatures. Under these conditions, the insulating qualities of the Quad-Lock panels should sufficiently insulate the concrete long enough for the curing process to complete.
- Tops of walls should be covered with insulation immediately after pouring.

Cold Weather Concreting

Cold weather mix:

- Order hot water added
- Order accelerator
  - Non-chloride

At the site:

- Choose timing well
- Minimize delays
  - Take advantage of embodied heat from concrete

Hot Weather Concreting

Cool the concrete:

- Chilled water from plant
- Ice from plant
- Add a retarding agent

Cool the forms:

- Pour early in the day
- Spray water to dissipate heat via evaporation
- Shade rebar from sun

Concrete Review

Concrete mix is critical

- Aggregate size
- Slump during pour
- Added components
  - Fly ash
  - Plasticizer
  - Water reducer
- Temperature conditions
- Transit time from plant

Placement is critical

- Pump size and speed
- Distance of drop
- Means of consolidation
  - Internal vibrator
  - Rodding
  - External vibrator

The Bottom Line: ***You get one shot with concrete!***

Know what you are doing, or get someone who does!

Recessed Lighting

- The recessed cans will be cut into the concrete floor/ceiling ICF structures and conduit will be run before or after pouring concrete.
- We will utilize low heat/low energy LED bulbs.

Low Voltage Boxes & Conduit

- Wall outlets and wiring for telephone, Internet, home music/theatre, home security, and TV cables will be inserted into the ICF prior to pour.
- In accordance with building codes, these low voltage wires and cables will be run in separate conduit and run perpendicular to high voltage conduit in order to avoid electrical interference.

Sheetrock, Flooring & Siding Alternatives

- Aesthetic tongue and groove pine can be used as a cost effective alternative to sheetrock for ceiling and wall coverings, particularly in conjunction with using aesthetic lodge logs (10-12” in diameter), pine beams, or glue laminates in place of conventional shoring.
- Material costs for decking and paneling can be less than drywall, e.g., as little as $16 per 4x8 area using 1x6 or 1x8 tongue and groove pine or fir with less labor required for the finished look (no taping, mudding, or texturing).
- Similar products can also be used for flooring and siding.

Fir Beams with Pine Tongue & Groove Ceiling

These beams or similar type material (milled logs or GluLams) would run perpendicular to Quad-Deck panels in the loft/2nd story of the PHMH (replacing inefficient attic space with value added living space).

Elimination of Conventional Shoring

- Once aesthetic lodge logs are used to provide shoring for custom engineered Quad-Deck panels, inexpensive and beautiful natural pine or fir decking will be used (in place of more expensive sheetrock) prior to putting Quad-Deck panels in place.
- This innovative technique can largely reduce labor associated with conventional shoring while adding substantial value and warmth to home.

Paneling, Edge V roof Decking, and Flooring

Flooring & Siding Alternatives

- Natural pine and fir products can also provide economic alternatives to conventional hardwood flooring and siding.
- Treated products can be used in similar fashion as conventional siding, providing either a modern look or a rustic pine look.
- Covered areas sheltered from the sun and elements are ideal for exterior applications using softwood siding.

1x6 Douglas Fir End Matched Flooring

Wavy Edge Bevel Siding

Wavy Edge Bevel Siding

Green Building Approach

- The PHMH will be built almost entirely from beetle kill pine, and its blue tinged wood will line the inner sanctum including log/beam accents, cabinets, ceiling paneling, flooring, and deck.
- The wood for the railings, posts, stairs & cabinets will come from nearby Idaho and PNW forests that have been drastically impacted from by 'beetle-killed' pine trees.
- While having drastic ecological impacts, this situation has also created a surplus of timber. All of the lumber used for the PHMH will be milled locally, likely coming from within a 75 mile radius where the house will be built.

Cabinets & Heavy Items

- Chalk lines will be utilized to mark location of cabinets on ICF walls before decking, paneling and drywall installation.
- ½-3/4” plywood (or other thickness depending on paneling, decking, or drywall thickness) will be fastened to the ICF wall using spray foam and screws via the plastic tie flanges inside the cabinet area.
- Decking or drywall will then be installed by butting up to the cabinet plywood.
- When necessary, concrete anchor bolts can be utilized to secure heavy items.

Viega Hybrid Copper & PEX

- Time saving PEX tubing and fittings can be used for entire residential applications with the exception of the water meter.
- Both labor and material costs are reduced.

Viega ProPress System

- The ProPress System is the fastest, most reliable, flameless way to press copper tubing.
  - Much faster than soldering (reduce labor by 75%).
  - Safer–no flame.
  - Cleaner–no solder, flux.
  - Convenient–one tool, one source of fittings.
  - Over 25 years of proven performance worldwide.
  - Highest quality.
  - Patented Smart Connect® feature.
  - Wide selection of sizes, types.
  - Meets/exceeds industry standards.
  - Guaranteed reliability.

Viega Hybrid Copper & PEX System

- Provides flexibility and versatility by combining copper and PEX tubing and fittings.

Centralized Parallel Water Distribution System

- A Viega parallel system provides the lowest pressure and temperature fluctuations in a plumbing system. Since each tubing line is dedicated to an individual fixture, interference between fixtures is eliminated. Additionally, specific fixtures can be supplied by smaller diameter tubing depending on the actual amount of water needed.
- For this type of installation, Viega offers the revolutionary MANABLOC parallel water distribution system, incorporating ViegaPEX tubing and Viega PureFlow PEX Press or PEX Crimp fittings. The Viega MANABLOC system provides a central location to control all plumbing lines and helps homeowners save energy costs and reduce water waste.

Viega MANABLOC parallel water distribution manifold

- Incorporates a system of PEX distribution lines dedicated to individual plumbing fixtures. Because dedicated tubing lines are plumbed specifically to each individual faucet, wait time for hot water is significantly decreased.
- Viega MANABLOCs arrive fully assembled and factory tested. They include individual quarter-turn port shutoff valves, which allow the end user complete control over the entire plumbing system from one central location. Fewer behind-the-wall fittings make it easy to install and less likely to leak. Flexible ViegaPEX tubing in 3/8" and 1/2" ensures optimal efficiency required to supply fixtures.

Energy & Water Conservation

- The choice to install 3/8" PEX tubing for low-demand fixtures instead of 1/2" will determine how much water an end user can save with a Viega MANABLOC system. In a length of 50 feet of PEX tubing, 3/8" PEX stores only .32 gallons of water (as opposed to 1/2" PEX tubing's .46 gallons). Storing less volume of water means less time is required to purge the line and deliver hot water twice as fast as with a 1/2" PEX line.
- Viega MANABLOC is a complete plumbing system that is easy to install and provides fast hot water delivery by decreasing energy costs and reducing water waste.

Viega MANABLOC system

Passive Solar Energy

- A passive solar home requires five elements to take full advantage of the sun's free heat:
  - orientation of the structure (and strategic design and placement of specific high and low gain glazing systems)
  - apertures (windows with high SHGC) to let in the sun's warming rays
  - a means of preventing too much solar gain in the summer (eaves)
  - an absorber surface that minimizes reflection
  - thermal mass to store the heat until it's needed (ICF construction of floors, walls, and ceiling)
  - a distribution system to move the heat to where it's required

Viega MANABLOC Features & Benefits

- Easy to install on each floor for residential applications
- Reduces wasted water
- Increased energy savings
- Delivers hot water fast
- Greater temperature and pressure balance during multiple fixture use
- Complete control of the plumbing system from a central location
- 1-1/4" internal reservoirs help maintain equal pressure during operation
- PLS plastic (polysulfone) resist aggressive water and corrosion
- 10 year limited warranty

Solar Gain & Thermal Mass

- For a truly passive house, each of these elements should operate without mechanical power or occupant intervention.
- As examples, summer solar gain is handled by properly designed overhangs. The distribution system would be natural convection within an open floor plan, with storage and release handled by concrete—a massive and dense material with high specific heat (heat storage capacity per unit volume) and moderate thermal diffusivity (the propensity of heat to dissipate to all areas of the mass).

Ratio of South Glass to Floor & Thermal Mass

- Perhaps the least-understood elements of passive solar design, and the ones that plagued the early passive solar pioneers in the 1970s, are the ratios of south glass area to floor area and of south glass area to thermal mass.
- Without proper balance—and an appropriate absorber and mass storage—an otherwise well-designed house can be unlivable.

Achieving Balance

- Too much glass or inadequate thermal mass can result in:
  - overheating even in the dead of winter
  - over-chilling at night
  - too little privacy
  - too little usable wall space
  - too much glare and shadow
  - too little sense of enclosure and security

Thermal Mass & Window Area

- Without sufficient thermal mass an adequate glass-to-floor ratio can lead to daily or even hourly temperature swings and heat stratification that can make a home uncomfortable.
- The south-facing glazing design standard for today’s passive solar homes is a window area between 7% and 12% of floor area. (For example, a 1,000-square-foot space would have between 70 and 120 square feet of south glazing.)

Active Solar Range

- The floor to window area ratio can apply to the entire house if all stories are to be passive solar designed, or just to the primary living floor.
- Beyond 12%, we enter the active solar range in which direct-gain thermal mass is not sufficient to maintain a uniform and comfortable indoor temperature without fans or pumps to move the heat to remote storage and retrieve it on demand.

SW Orientation

- In order to optimize solar energy (photovoltaic panels and solar radiation via passive windows during the winter) the PHMH will be oriented to the south.
- Exterior shades will be utilized in addition to 3’ eaves to reduce the effects of solar radiation in the summer while capturing warmth and day-lighting in the winter through passive solar radiation.

Optimum Window Size

- The most appropriate size of windows for energy smart design depends on building orientation and the amount of thermal mass in the internal building materials.
- The total glass area is best kept between 20–25% of the total floor area for brick veneer houses and 22–30% for double-brick or ICF houses.

Window Design & Shading Principles

The three main principles of energy smart window design and placement in the Northern Hemisphere are:

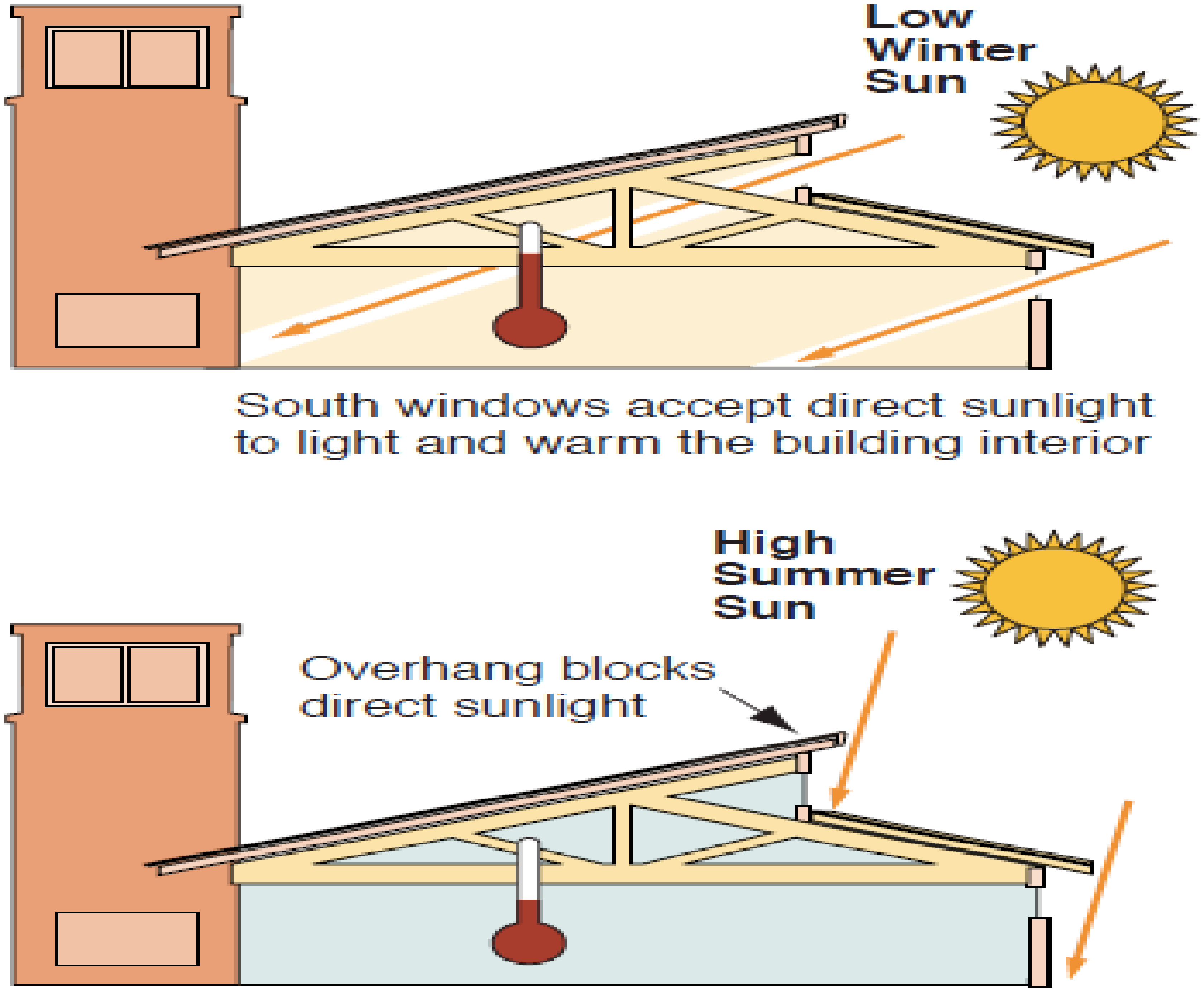
- Maximize winter heat gain by orientating windows to the south and sizing windows to suit the amount of thermal mass in the dwelling.
- Minimize winter heat loss through appropriate window sizing, together with double or triple glazing, storm windows, and/or close-fitting internal coverings such blinds and drapes with pelmets.
- Minimize summer heat gain by protecting windows with external shading devices, and through appropriate sizing and positioning of windows.

Eaves & Solar Control

- An overhang/eave, or some sort of solar control or solar shading, is a crucial element in passive solar design because it blocks the sun's heat energy when it is not desired.
- Because the sun travels different paths across the sky in the winter (low) and summer (high) time, eaves can be constructed to utilize and manipulate the heat energy from the sun.

Solar Radiation

- The following diagram shows how an overhang (or 3’ eaves) can be constructed to allow the winter sun in, while it keeps the summer sun from hitting the dwelling.
- There is an additional outline showing the possibility of having sloped south wall with glazing (glass).
- While having sloped glass allows for the greater potential of winter heat energy storage from the sun, care must be taken to keep the building from overheating in the summertime.


Low Winter Sun
South windows accept direct sunlight to light and warm the building interior
High Summer Sun
Overhang blocks direct sunlight

Passive Solar Houses

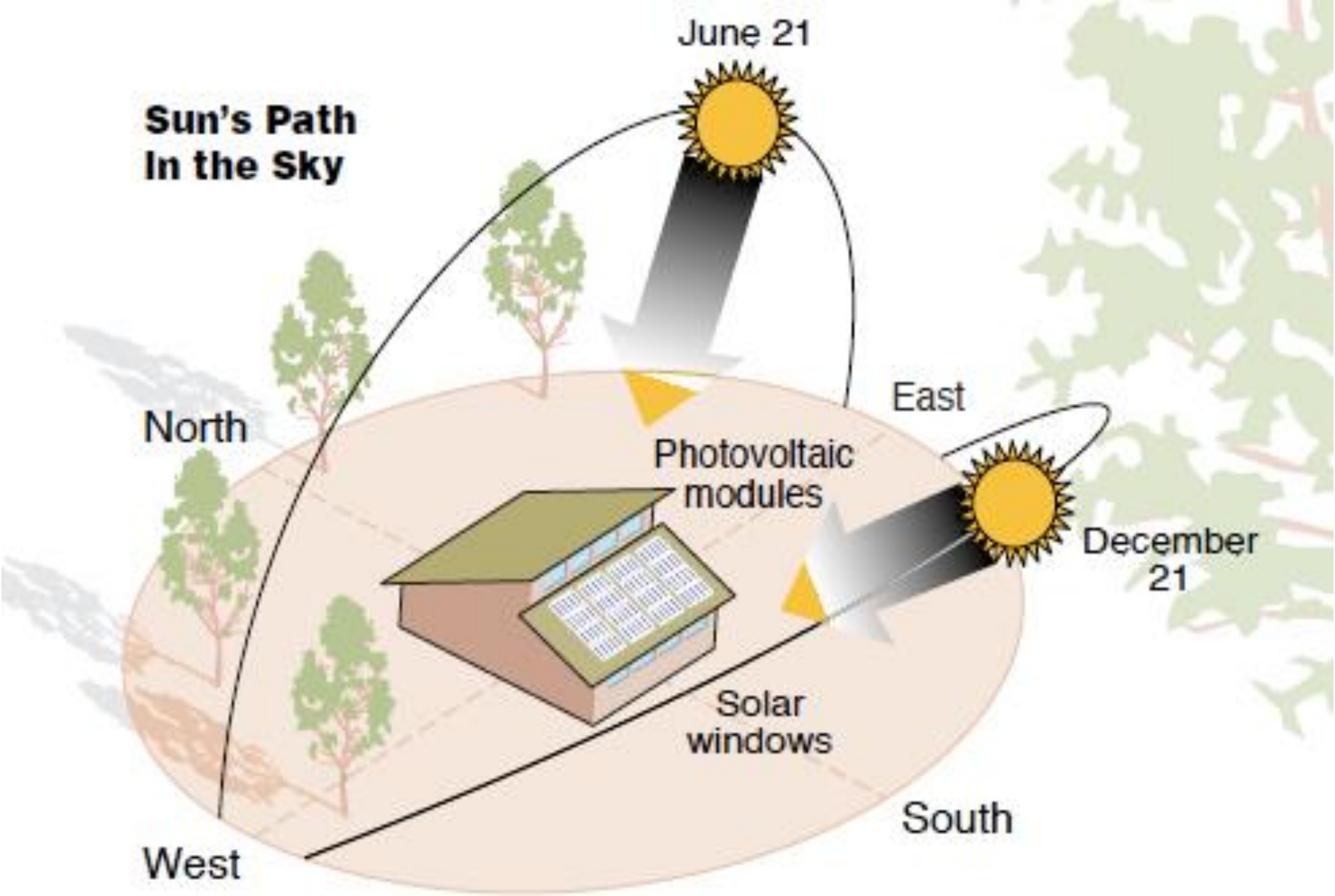
- In order to stay cool in the summer, passive solar houses rely on a system of shading (and/or an overhang such as eaves) to keep the building cool.
- Simply by building in this way, a house can reduce its heating and cooling costs by 85%.
- In the summer, as temperatures rise, a passive solar building uses its thermal mass to help keep the building cool. In order for this to happen, the summer sun is kept from reaching the thermal mass of the building.
- The concrete floors of the PHMH will aid in storing thermal energy by enhancing its thermal mass capacity.

Solar Orientation

- The summer sun's path aides in harboring passive solar energy by traveling high in the summer sky, thus a proper overhang or other type of system is needed to shade or cover the widow, in the summer so that the sun's heat energy is blocked or avoided when it is desired to have the building cooler than the outside temperature.
- A properly designed eave/overhang keeps the heat and energy from being absorbed into the house in the summer.

Summer & Winter Solstices

- As the Earth rotates around the sun on its annual cycle, it is tilted at an angle on its vertical axis.
- This impacts how the sun’s rays strike various locations on Earth. The Earth is its most extreme tilt at the winter and summer solstices.
- The sun appears to rise in the east and it sets in the west. In actuality, the Earth is rotating on its axis and around the sun.


Sun's Path
In the Sky
June 21
North
East
Photovoltaic
modules
December
21
Solar
windows
South
West

The Earth's Orbit & Axis

- The seasonal position of the earth's orbit and turning axis affects how low or high the sun appears in relation to the horizon.
- In the winter, the sun is relatively low in the sky with its lowest arc through the sky on the winter solstice, on December 21^{st}.
- In the summer, the sun travels a high path through the sky and is at its highest angle on the summer solstice, on June 21^{st}.
- The equinox falls on the point between the solstices and indicates the arrival of spring or fall.

Utilizing Predictable Movements

- Passive solar design uses the predictable movements of the sun to best utilize its energy within the building’s overall design both for heating and cooling purposes.
- Many passive solar buildings also include active solar aspects, such as photovoltaic panels

Indigenous Deciduous Shade Trees

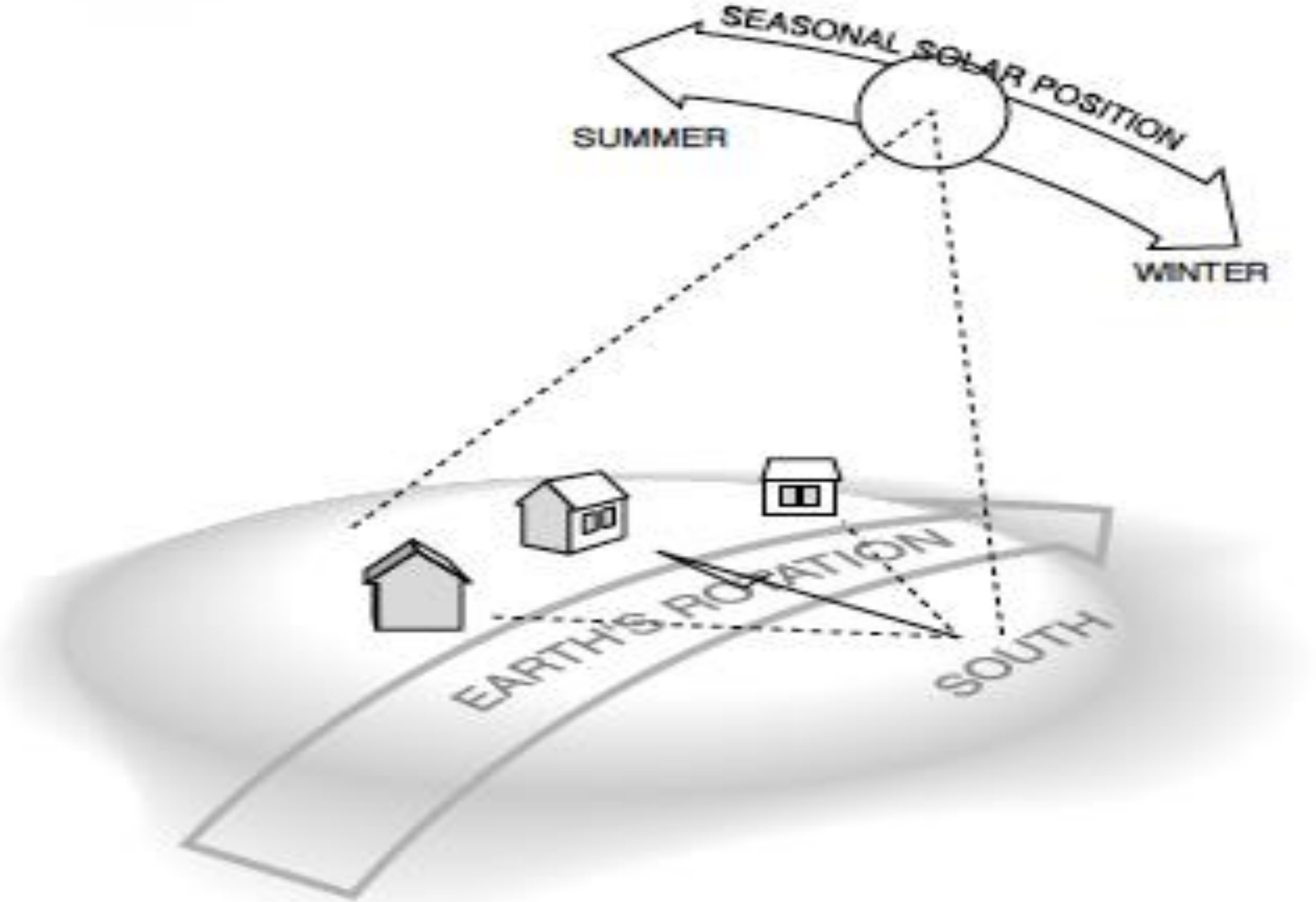
- In addition to using longer eaves/overhangs, and retractable window shades, incorporating deciduous shade trees into landscaping provides a natural way to provide shade in the summer, and passive solar radiation for the windows in the winter.
- Large indigenous shade trees will be utilized in the landscaping of the PHMH.

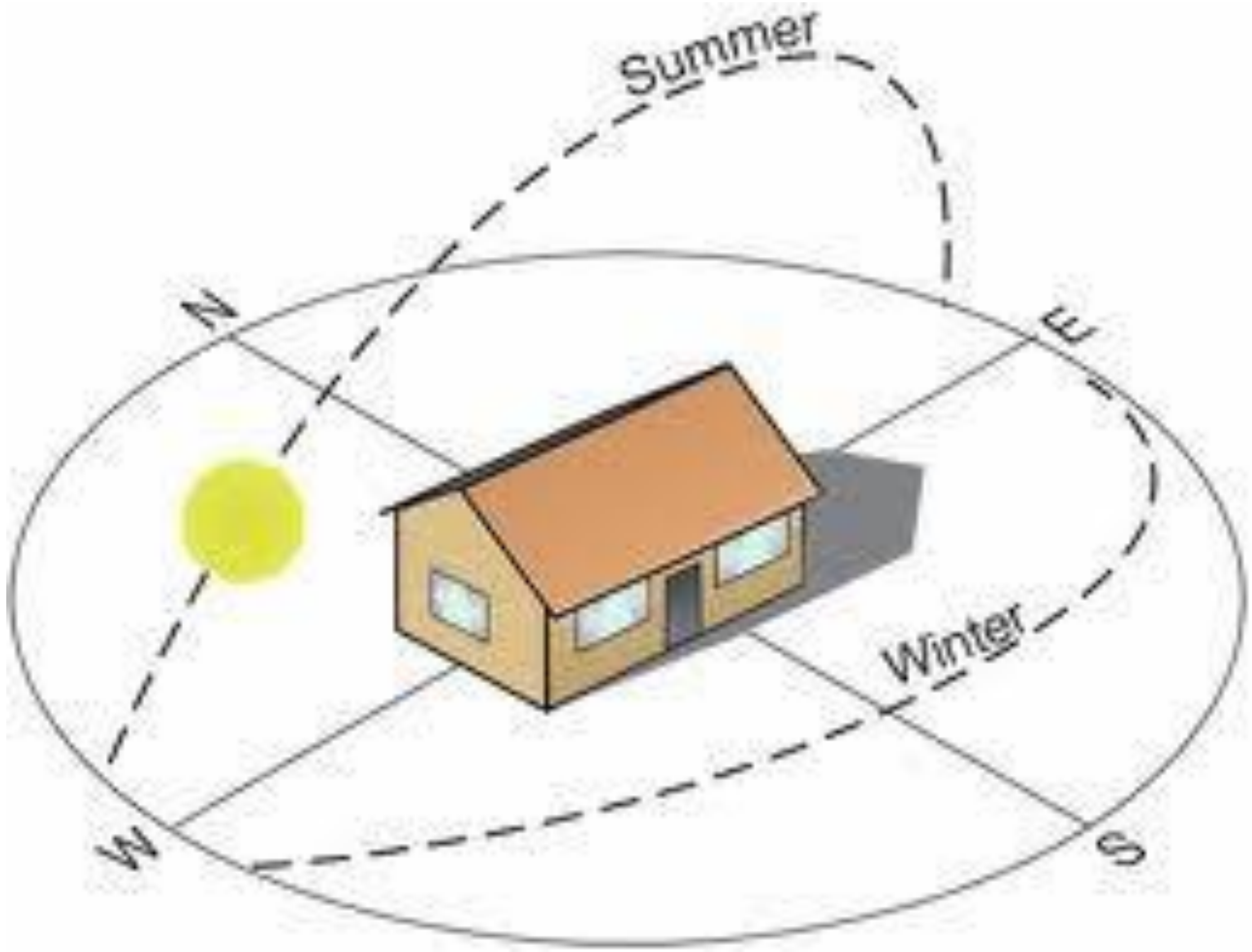
Building Orientation

- Because the sun rises in the east and sets in the west, the side of the building that is utilized for solar gain needs to be facing the south to take maximum advantage of the sun’s potential energy.
- If the building’s axis is located on the east-west direction with its longest dimension facing the south, more of the building is situated to absorb the sun’s heat energy.

Passive Solar Rectangular Shape

- Passive solar buildings are typically rectangular with the long side of the building facing south.
- The distance from the source of incoming heat (south) to where it is absorbed (typically a northern wall) should be minimized.
- The resulting shape is a rectangle.
- Efforts will be made to locate a lot that is ideal for orienting a rectangular PHMH facing south.


SEASONAL SOLAR POSITION
SUMMER
WINTER
EARTH'S ROTATION
SOUTH


Summer
N
E
W
S
Winter

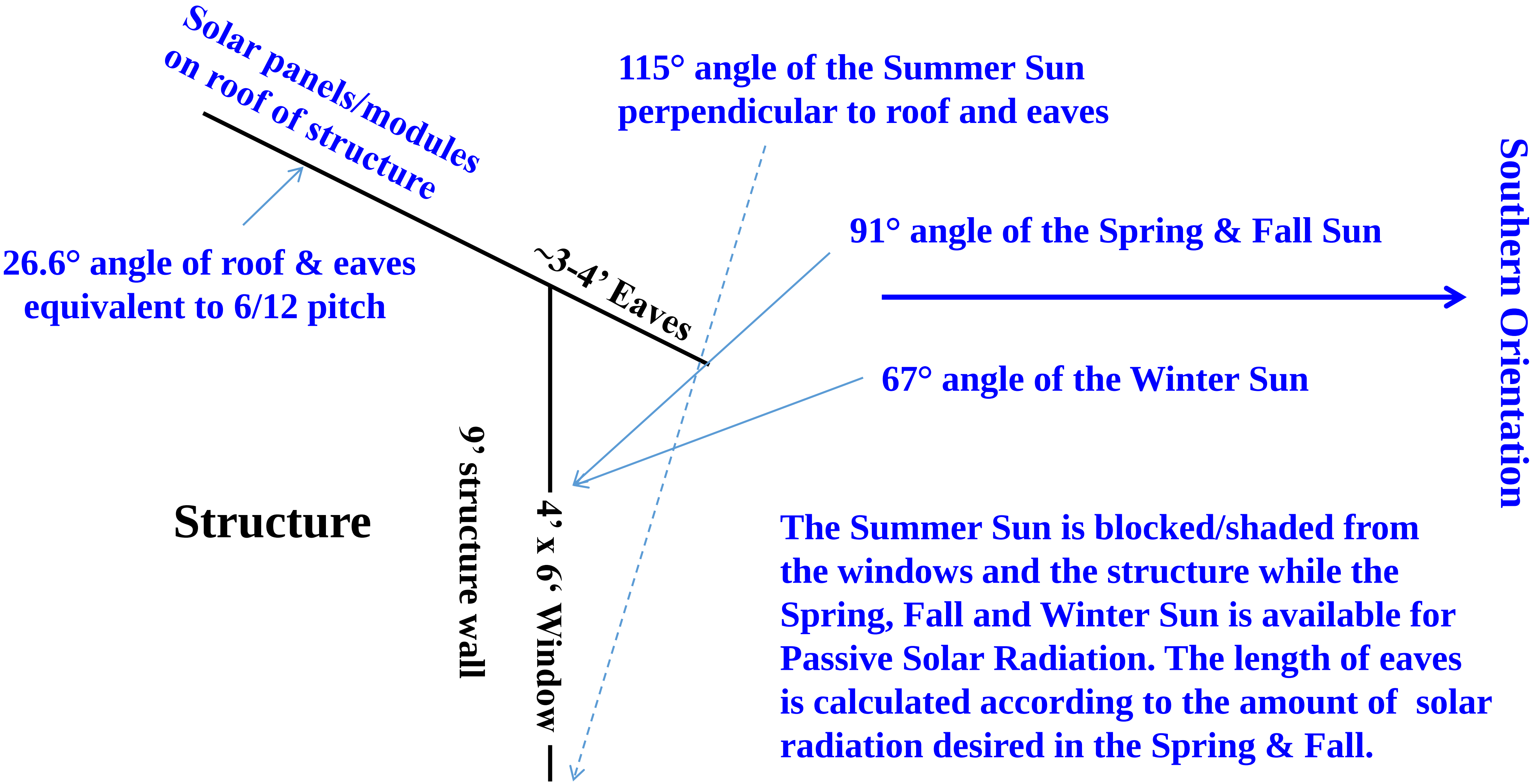
Calculating Overhang of Eaves for Homes in Boise, ID

Seasonal angle of the sun - degrees from vertical:

- On the 21st December, the sun will rise 67° east of due south and set 67° west of due south.
- On the 21st March/21st September, the sun will rise 91° east of due south and set 91° west of due south.
- On the 21st June, the sun will rise 115° east of due south and set 115° west of due south.

(This information can also be used to strategically adjust PV panels and thin film PV modules for maximizing efficiency of solar power systems, particularly through solar power arrays and solar tracking systems powered by an electric motor to provide up to 45% additional yields.)

Calculating Overhang of Eaves & Pitch of Roof for Homes in Boise, ID



The Summer Sun is blocked/shaded from the windows and the structure while the Spring, Fall and Winter Sun is available for Passive Solar Radiation. The length of eaves is calculated according to the amount of solar radiation desired in the Spring & Fall.

South Facing Windows

- It is ideal to have the windows (solar glazing) within 5° of true south. However, windows that are within 15° of true south are said to function *almost* as well.
- As the degree difference from true south expands, the overall potential solar efficiency of the structure decreases.
- As a result, larger amounts of supplementary energy may be needed to heat the building in the winter.
- As the building’s glass (glazing) faces more to the southwest, more energy may be needed for summer cooling.

Southern Solar Glazing

- Passive solar buildings typically have many windows facing the south
- Southern facing windows (southern solar glazing) are a vital component for a passive solar design and building.
- Because the southern side of the building is the side that will potentially receive sunlight throughout the day, most passive solar buildings will feature glass dominating the southern side.
- Southern facing glass allows the sun’s energy to be absorbed and distributed through the building’s thermal mass.

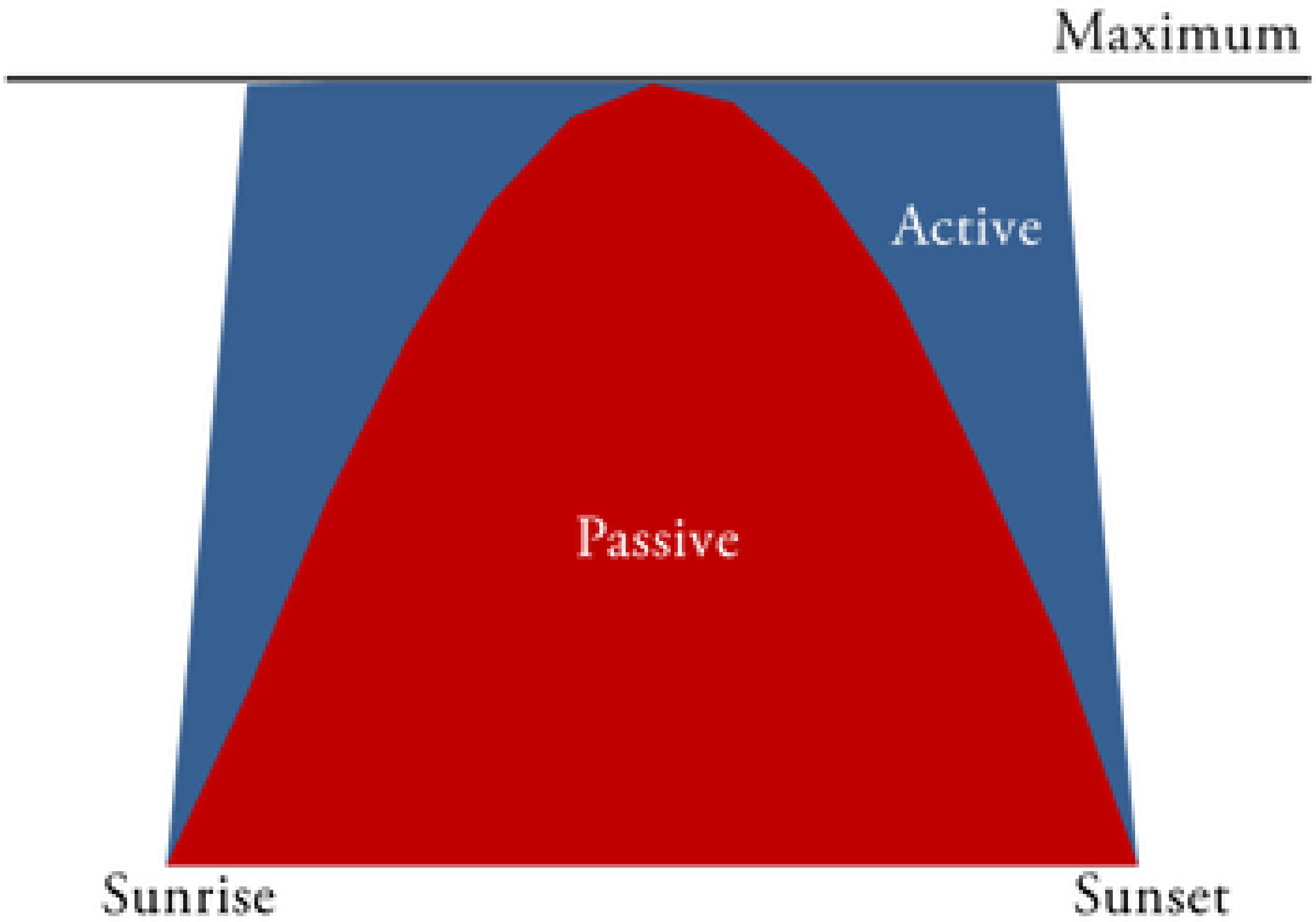
Glazing, Shades & Awnings

- Glazing is the fancy architectural word typically used for southern facing glass that has the capacity to transfer the sun’s energy.
- Another benefit of having windows on the south side, is that it allows natural light to bathe the house throughout the day. This aspect will lower energy use throughout the PHMH since it minimizes the use of artificial light.
- While southern facing windows (glazing) are a necessary component of passive solar design, electric shades and retractable awnings will be used to insulate them in the winter after the sun goes down, and shade them in the summer.

Active vs. Passive Solar Power Systems

- A fixed, **passive** solar system captures less of the sun’s rays than an **active** dual-axis tracking system.
- When the sun is rising or setting it only shines a small amount of light on the fixed panel in the morning and the evening times.
- A two axis solar tracker points the panels in the optimal direction all day, everyday.

Active Solar Increase

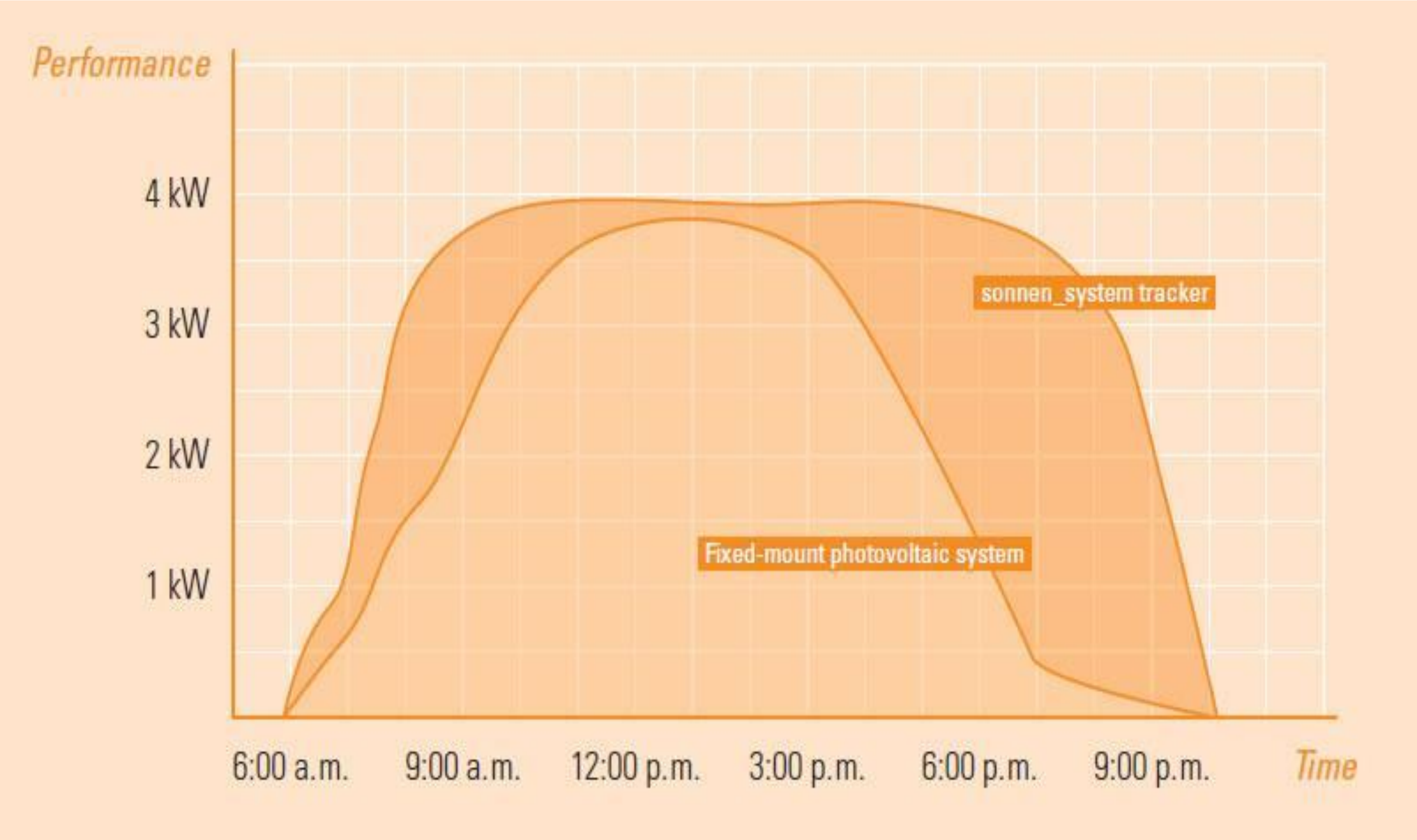


Maximizing Solar Power

- By tracking over the course of an average day, this translates to about 40% more power from the same amount of panels as a fixed panel system and up to 50% or more during the summer days.
- The graph above shows how much energy is being generated throughout an average day by **Active Solar** (blue) and a passive system (red).

Dual-Axis Solar Tracking System

Solar Tracker Performance



NREL’s Solar Redbook

- 30 years of data collection by the National Renewable Energy Lab (NREL) reveals that on average, Boise, ID has 7.1 hr. (kWh/m^2/day) of sun days.
- This is based on solar radiation for a dual Axis tracker with flat-plate collectors (kWh/m^2/day) +/- 9% (in contrast to fixed single Axis tilt of 4.5 hr. sun days, and 6.3 hr. sun days for a single Axis tracker).

NREL's PVWatts Calculator

- However, according to NREL's PVWatts online calculator average annual production (due to various inefficiencies) for active dual axis PV technologies is only 1.928 kWh/m^2/day; and for passive single axis tilt it is only 1.365 kWh/m^2/day (considerable room for improvement as PV technology is currently only 18% efficient).
- "Sun day" hours are 15%-45% less for ground mounted and roof mounted fixed PV panel systems.

Sonnen Systems Tracker Technology

- Biaxial tracking system for photovoltaic installations
- Astronomical control based on local coordinates
- Centralized monitoring via Internet
- Comprehensive safety concept: the safeguard
- Building integration feasible
- Additional yield up to 45% compared to fixed-mount installations
- Track-back function to prevent cross-shading
- 20-year warranty (depending on service agreement)
- Suitable for all panel brands

Solar Tracking Systems

- Stand alone structures with concrete footings or can be mounted on buildings (ICF structures)
- 19-60 m^2 (4.75-15 kW) solar arrays
- Maximum installation height – 66’
- Weight – 1480 lb.
- Angular range – azimuth 270°/elevation 70°
- Angular accuracy by 0.1° - 0.25°
- Wind alert system operates at wind speed ≥ 29 mph
- Monitoring system for the entire plant via SMA Sunny WebBox

Remote Monitoring via track_app™

- track_app™ is a truly portable solution for monitoring and operating sonnen_system trackers and SMA inverters remotely.
- Available for both iPhone and iPad, track_app™ is a simple and intuitive application with an integrated display of real-time tracking performance, enabling data system operators to be in complete control no matter their location.

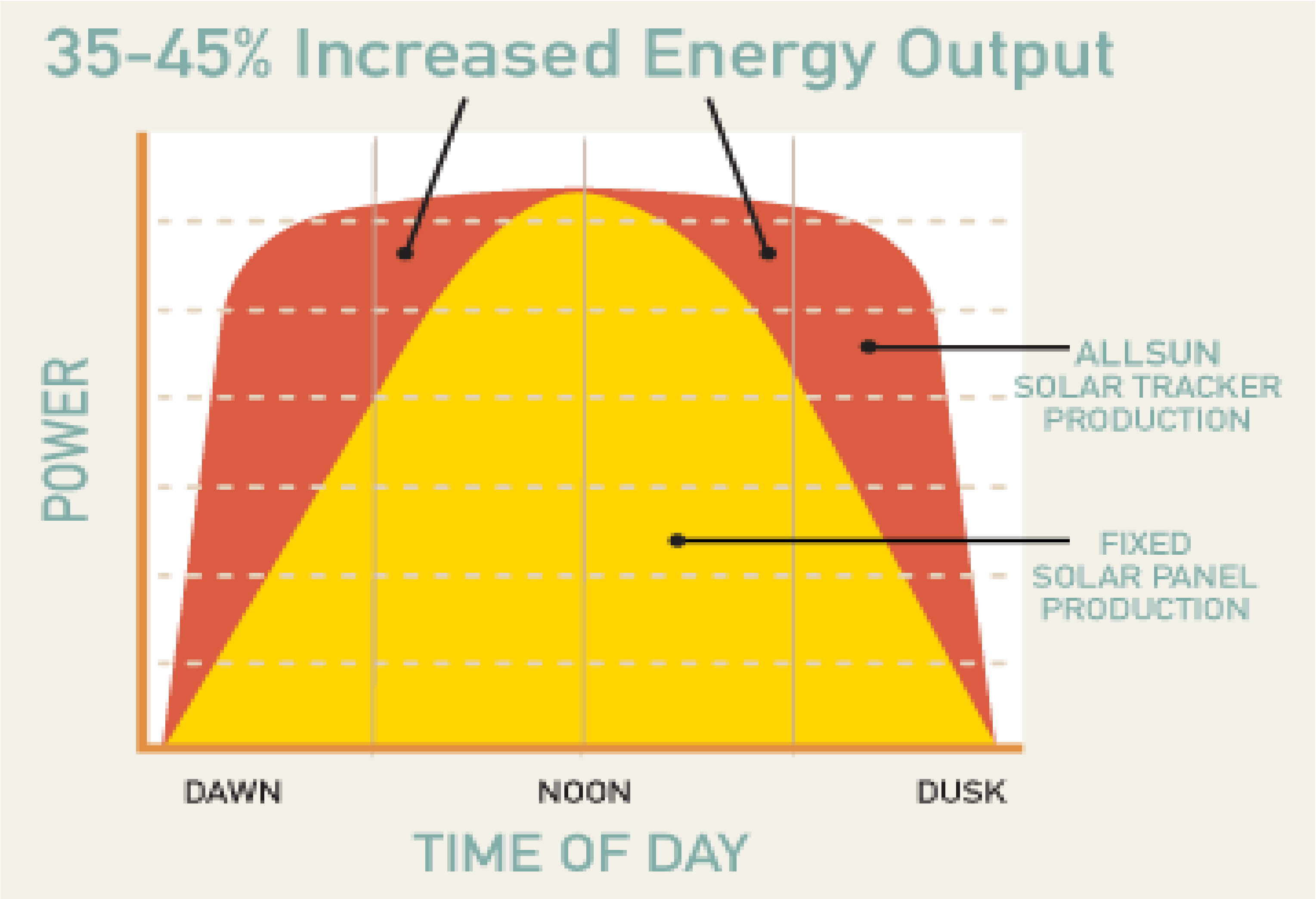
“track_app™” Mobile Technology

Active Solar via Dual Axis Tracker Return on Investment

- US companies such as Wattsun Solar Trackers and All Earth Renewables provide similar solar tracking systems ranging from 1.5-7 kW for about $4.50/kW installed (~$0.85-$1/watt for PV panels).
- This is similar in price to what some fixed solar panels are currently being installed for including labor.
- Fixed solar panels and installation kits can be purchased from wholesale distributors for about $0.62/watt and $1.40/watt respectively.
- Based on these prices, the 35-45% increase in power production could provide an immediate ROI in comparison with less efficient fixed or passive PV panels.

All Earth Renewables Solar Tracking System

All Earth Renewables Solar Tracker Production



Electricity Demands for an all Electric Net-Zero Home

- For the average home using about 12,000 kWh (~18000 kWh for all electric) annually, a passive house can reduce that to about 3,000 - 6,000 kWh annually for all electric appliances including stove/oven, dryer, and water heater.
- That equates to a total energy load of 4.1-8.2 kWh/day for zero net energy homes using passive house construction.

Calculating Capacity of a Solar Power System

- The capacity of solar power systems is based on the amount of peak energy that can be produced per hour of sunlight.
- Thus, a 1 kW solar power system is capable of producing 1 kW per hour of sun light.
- Allowing for inefficiencies in the PV panels, hot environments, and inverters, a conservative 4 hour “sun day” is about what can be expected on average in Boise, ID for a passive system.
- Five to seven hour sun days can be achieved on sunny days, particularly via the use of solar tracker technology.

Active Solar Power System

- On average, an active solar power system will produce 30-45% more power than a passive solar power system.
- However, for conservative purposes, we will use a 1.9 hour sun day for calculating power capacity for both active and passive systems in Boise, ID.
- Hence, a 4.1-8.2 kWh energy load would require a 2-4kW solar tracker.
- Larger than normal homes with all electric appliances could require a 4-6kW system.

Wattsun Solar Trackers
AZ-125 & AZ-225 Azimuth Models

- 4-6 (250 watt) panel (1-1.5 kW system) solar tracker - $2,284 (e.g., about $1.52-$2.28/watt or $0.11-0.13/kWh for 1.9-2.85 kWh/day without panels over a 25 year period not including maintenance)
- 9 panel (2.25 kW system) solar tracker - $4,200 (e.g., about $1.86/watt or $0.11/kWh for 4.275 kWh/day without panels, etc.)
- 12 panel (3 kW system) solar tracker - $5,200 (e.g., about $1.73/watt or $0.10/kWh for 5.7 kWh/day without panels, etc.)

Structural & Mechanical Features/Specifications

Tracking Type	Dual Axis Azimuth/Elevation AZ-125 Dual Axis Optional
Azimuth Range of Motion	270°
Elevation Tilt Angle	5° to 75°
Motor Power Consumption, Azimuth	Daily watt-hours From 10 w-h DC to 20 w-h DC
Drive Type	Gear Drive
Elevation Motor Type	Heavy Duty Linear Actuator
Motor Type	1/15 HP, 24 VDC Nominal
East-West/North-South Dimensions Array	Site/module specific
Height	Site/module specific
Modules Supported	Most commercially available
Module Configuration	Landscape/ module specific
Module Attachment	Proprietary extrusion/ std. mounting bolts
Materials	High-strength galvanized steel & anodized aluminum
Allowable Wind Load	IBC 90 MPH, 3-second gust exposure C

Additional Features & Specifications

ELECTRONIC CONTROLLER FEATURES/SPECIFICATIONS	
Solar Tracking Method	Closed Loop Optical
Control Electronics	Proprietary
Tracking Accuracy	+ or – 2° standard, field adjustable
INSTALLATION, OPERATION & MAINTENANCE	
Gear Drives	Grease every 1 year
GENERAL	
Energy Gain vs. Fixed-Tilt	Up to 40%, site specific
Warranty	2 years parts only, 5 year extended available
Made in the USA	Yes

Azimuth AZ-125/AZ-225
Wattsun Solar Trackers

Wattsun Solar Trackers
Division of Array Technologies

- Wattsun is currently in the process of coming out with a 20 panel (5 kW) single axis solar tracker - $??
- Though this single axis tracker will be 6-7% less efficient than a dual axis tracker, it will also be less expensive.
- Most commercial solar power fields use only single axis technology in their solar trackers.
- Solar trackers use very low horsepower (1/15) motors that are very efficient to operate and economical to maintain.

PV Mono/Poly Crystalline Panels

- 250-300 watt panels can currently be purchased wholesale from www.RENVU.com and www.wholesaleSolar.com for as low as $0.65/watt and up with added incentives such as free racking systems occasionally offered by Wholesale Solar.
- This is about $0.20-$0.30/watt lower for panels, e.g., about 40-60% less than purchasing panels and racking systems directly through solar tracker manufacturers and most solar retail outlets.
- This allows for providing solar tracking and racking systems for about $1.20-$3.38/watt, or $0.05-0.13/kWh not including installation costs and 30% mark-up for materials and equipment, all of which qualify for the 30% Federal tax credit.

Labor & Installation

- $1.20-$3.38/watt, or $0.05-$0.13/kWh not including installation and 30% mark-up for materials and equipment would amount to about $3.40-$6.76/watt.
- However, the 30% tax credit for solar power systems would proportionately reduce the amount paid per watt.

Larger Solar Trackers

- AllSun Trackers by All Earth Renewables begin at 5kW, are more sturdy than Wattsun trackers, and are guided by GPS which makes them more reliable than sun guided systems.
- Sonnen Systems begin at about 7kW and are considerably smaller than the 66’ commercial models for use in the residential market.

All Electric Net-Zero Homes

- For an all-electric passive home (e.g., stove/oven, dryer, and water heater), the ROI could be less than 3 years.
- For a new home in which the solar tracker is financed, the energy savings should provide an immediate ROI in comparison with the amortized portion of the mortgage used to pay for the active solar power system.

Average Size Solar Tracking System for Passive Homes

- The average size passive home would use less than 4-8 kWh/day.
- So in most cases the average sized passive home would require only a 2-4 kW solar tracker and racking system.
- For a 30 year mortgage at 5% interest, the portion of the monthly mortgage payment for installing a 2-4 kW solar tracking system (about $4,800-$9,600) would be only $26-$52.

Cash Flow for Zero Net Energy Homes

- The cost of electricity in Idaho is currently ~$0.072/kWh and going up each year (since Idaho Power built a new 5 MW natural gas power plant that they are paying for and passing the cost onto consumers).
- Hence, the current monthly power bill for the average home is $72. Thus, this scenario reflects a positive cash flow from day one for Zero Net Energy homes using passive house construction.
- The cost of solar PV technology has decreased by 80% over the last few years. In addition, the cost of installation has also come down.
- As the cost of electricity from the grid continues to increase, the savings for solar PV systems will continue to increase.

All-Electric Appliances

- For all electric appliances, the average kWh could be 50% higher, e.g., 18,000 kWh annually.
- For a 90% increase in energy efficiency for a passive house, that would result in increasing the size of the solar tracker and racking system from 1.5kW up to 3kW.
- However, the monthly power bill would increase to $108, providing a savings of around $70/month.

Economics of Active vs. Passive Solar Power Systems

- The 30-45% increase in yield for a solar tracking system would provide an immediate cash flow for new home construction (in which the 20% increase in cost for the solar tracking system is amortized over a thirty year period via a mortgage).

Structural Mounting

- For the residential market, solar tracking systems could be installed on the roofs of ICF structures.
- ICF roofs and mounting area could be engineered to accommodate a safe and secure roof mount for new construction.
- This could alleviate concerns for liability and provide safe access for annual maintenance, e.g., lubricating the gears.
- This could substantially expand the potential market for residential applications.

What is Net Metering?

- Net metering is a program that allows customers to generate power on their property and connect it to a utility’s power system.
- The electric meter “spins” backwards, providing a credit for energy produced against charges for energy used.
- Systems connected to the grid are referred to as “interconnected” or grid connected power systems.

How does Net Metering work?

- For residential and small commercial customers, the renewable source of generation is connected on the customer’s side of the electric meter. Energy generated is consumed inside the residence first and any
- excess would flow from the meter to the power lines. At the end of the month, if consumption outpaces production, a monthly power bill is sent to the customer for the energy consumed.
- If production outpaces consumption, a credit appears on the bill.

Buying & Selling Power

- How much would I be paid for my power and how much would I have to pay for the power I use?
- Residential and small commercial customers are paid for excess generation at the same base retail rate that they are charged for electricity.
- Other Idaho Power customer classes are paid under a different, calculated rate structure.

Building Net-Zero Homes

- In 2011, the average annual electricity consumption for a US residential utility customer was 11,280 kWh, an average of 940 kWh per month.
- By reducing the power load by 90%, a solar photovoltaic system producing only 100-200 kWh per month (~1-2 kW system) may be sufficient for conversion of a passive house to a net-zero home via net-metering.

Idaho Power Fees for Net-Metering

- Monthly fees for participating in the net-metering program are $5/month.
- Credits are issued for overage to discourage over-producing.
- There is currently no limit to the volume of power generation produced by the residential market.

Solar Photovoltaic Power Systems

- 8 Talesun 250 watt Solar Panels (660M) providing 2kW power for $1.15 /watt, e.g., $2300 on eBay (for solar panels only), or $0.68/watt via buying overstock volume by the pallet from www.renvu.com.
- 2kW Solar Kit Canadian 250P, SMA inverters, Mounting, for $2.44/watt, e.g., $4,880
- Grape Solar GS-2300-KIT Residential 2,300 Watt Grid-Tied Solar Power System Kit for $4/watt, e.g., $9,238 on Amazon (also available via Costco, Home Depot and Lowes.
- Pricing of panels and installation kits continue to come down, making solar PV power systems more and more affordable, particularly via tax credits.

Thin Film PV Module Technology

- Also called laminate PV material, provide an economic alternative to conventional PV (mono or poly crystalline silicon) panel technology.
- Lower cost and higher performance in hot sunny environments is available.
- Installation can be less labor intensive since racking systems are not required.
- Available from www.civicsolar.com
- Three primary types:
  - amorphous silicon (a-Si)
  - cadmium telluride (CdTe)
  - copper indium gallium selenide (CIGS)

Comparisons of Traditional Advantages & Disadvantages of Thin Film PV Technologies

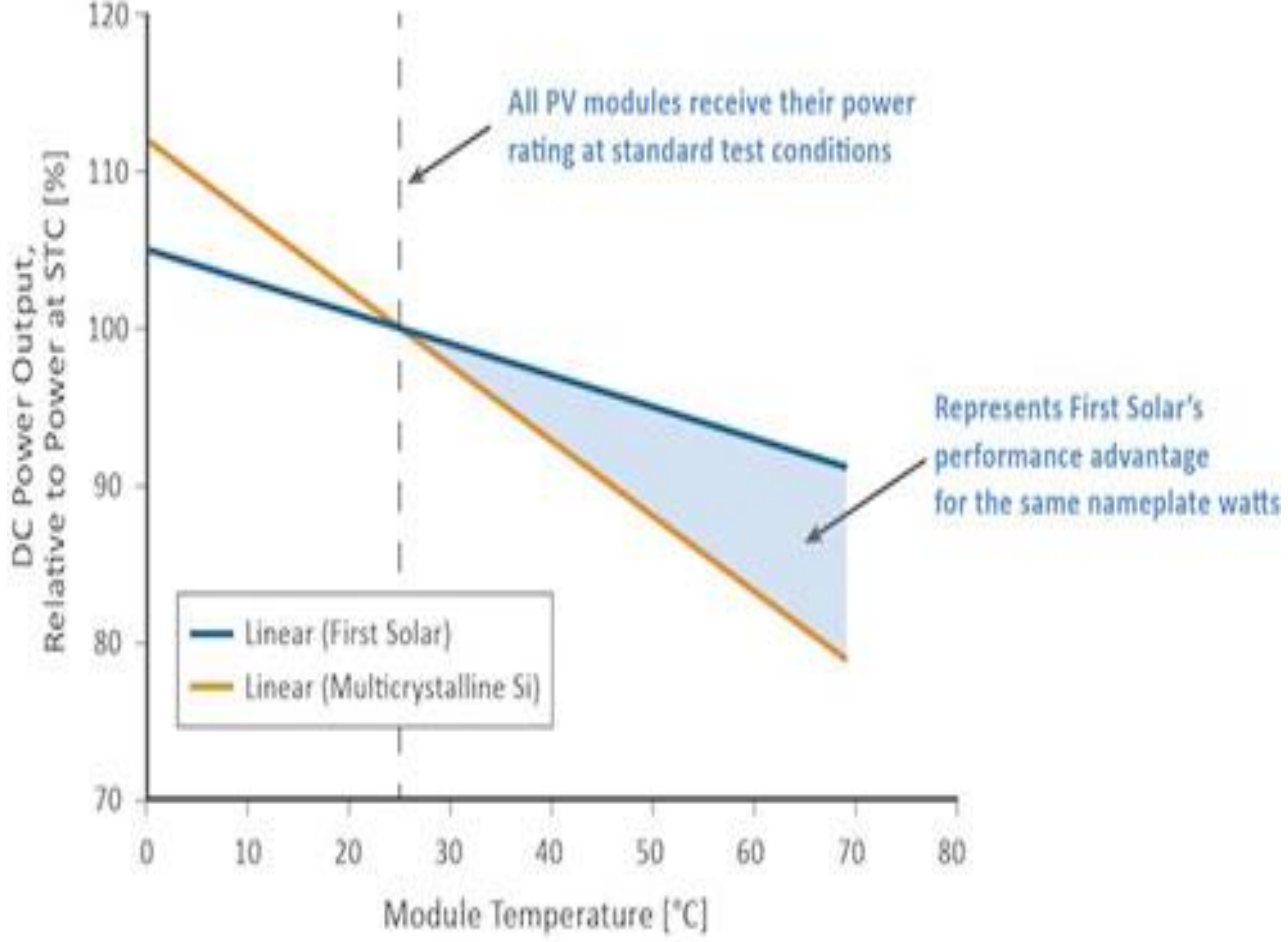
Technology	Maximum Demonstrated Efficiency for small cells*	Advantages	Disadvantages
a-Si	12.2%	Mature manufacturing technology	Low efficiency High equipment costs
CdTe	16.5%	Low-cost manufacturing	Medium efficiency Rigid glass substrate
CIGS	19.9%	High efficiency Glass or flexible substrates	Film uniformity challenge on large substrates Costly traditional processes

Advanced Thin Film PV Modules

- Wholesale cost is ~$0.75/watt for thin film cadmium telluride (CdTe) PV technology, about half the retail cost of conventional PV (crystalline silicon) panel technology.
- Thin film modules are the foundation to the world’s most advanced PV power plants, particularly in sunny and hot climates.
- Smallest carbon footprint and fastest energy payback time of any PV system.

Superior Performance

- With a proven performance advantage over crystalline silicon technologies, First Solar’s world-record holding CdTe thin film solar modules deliver higher energy yields at elevated temperatures due to a lower temperature coefficient.
- Beyond temperatures of 25°C, First Solar modules produce more energy for the same nameplate watts and provide stronger plant performance in high temperature climates than conventional PV panels.



All PV modules receive their power rating at standard test conditions
Represents First Solar's performance advantage for the same nameplate watts
Linear (First Solar)
Linear (Multicrystalline Si)
DC Power Output, Relative to Power at STC [%]
Module Temperature [°C]
120
110
100
90
80
70
0
10
20
30
40
50
60
70
80


Thin Film Photovoltaic (PV)
- On the roof to make electricity
Solar Panel
- To produce back up electricity for the pumps
Solar Evacuated Tubes
- To heat the house and supply domestic hot water

Proven Technology

- First Solar modules have been verified by independent engineers and certified to international performance and safety standards by third party laboratories around the world, including installations with NREL for over 16 years.
- First Solar modules are proven and backed by a limited 25-year power output warranty and a limited 10-year materials and workmanship warranty.

Certified for Reliability and Safety

- Certified for performance and safety according to IEC 61646, IEC 61730, and IEC 61701 (salt mist corrosion)
- Regionally certified to UL (North America), CEC (Australia), Golden Sun (China), and MCS (UK) standards
- Manufacturing certified to ISO 9001:2008 (quality), ISO 14001:2004 (environmental) and OHSAS 18001:2007 (occupational, health and safety) standards

Sun Power Energy Systems

- Alternatively, a solar powered system can be purchased directly from the manufacturer, e.g., SunPower to provide the highest energy efficiency (21.5%) in the industry.
- The system comes with an industry leading 25 year warranty and no down payment leases are available.
- There is currently an opportunity to become a distributor/dealer in the Boise, ID area.

Zero Net Energy Homes

- By reducing the energy load via Passive House design, grid-connected solar power systems for net-zero homes are affordable.
- The power provided by the net-metering system eliminates the need for charging batteries.
- For provision of backup power a natural gas or liquid fuel powered generator can be installed.

Additional Solar Energy System Benefits

- New research by the U.S. Department of Energy’s Lawrence Berkeley National Laboratory finds that installing a residential solar energy system increases a home’s value by an average of $17,000 in California.
- Though the average increase in value may be considerably less in other states, there is no doubt that it adds value to almost any home.

Smart Home Control Systems

- From geothermal and solar energy sources to forced-air and radiant distribution systems, and combinations thereof, the options for achieving indoor comfort are increasingly complex and the targets for efficiency increasingly rigorous.
- Smart Controls system, designed for residential and mid-range commercial buildings, enables intelligent integration and optimization of a building’s appliances and HVAC system components.

Internet Accessibility

- Smart Control Systems can be accessed with any Internet-accessible device. This allows for making adjustments to your indoor climate from practically any location in the world. Even if you're not on-site, you can still be sure your HVAC systems are optimized for maximum energy efficiency and comfort.
- While the appeal of the Smart Control system to homeowners may be primarily its convenience, for a commercial building where a few optimization adjustments can add thousands to the bottom line, Smart Controls is smart business.

Optimizing HVAC System Performance

- Smart Control systems are programmed to react to changes in your home/building’s environment, so it is working 24/7 to optimize HVAC system performance and indoor comfort.
- From your smart phone or any other Internet-enabled device, you also have access to monitor and update system settings, making system control even smarter.
- Allows you to set individual temperatures for each controlled zone.
- Stores and maintains your settings in a database accessible from anywhere in the world via the web.
- Optimizes and manages the combined use of heating, cooling and ventilation systems to achieve comfort with the lowest possible energy use.

Optimize HVAC System Performance cont.

- Interfaces with weather services, automatically adjusting settings in advance of changing weather conditions.
- Constantly monitors the health and functioning of the HVAC system and reports problems immediately.
- Permits you to define specific on/off events in your settings, so operation of water heater, forced-air and radiant systems can be coordinated to ensure the highest level of efficiency.
- Makes sophisticated controls technology user friendly with an easy-to-use, point-and-click interface accessed through a standard web browser.
- Allows service contractors to access your system and efficiently diagnose potential issues before arriving at your site.

PowerWise Complete Building Intelligence System

- insense™ Sensor Network
- inDAC™ Data Acquisition & Control
- eMonitor Gateway
- Circuit-Level Electrical Monitoring
- inServe™ Server w/Advanced Analytics
- inView Passive House Monitoring (recommended by PHIUS)

Sensors & Flow Meters

- CO_2 Multi Sensor
- PowerWise Multi Sensor
- Relative Humidity – Temp. Sensor
- Stainless Steel Temp. Sensor
- Gas Flow Meter
- Analog Flow Meter
- Pulse Flow Meter for Water or Glycol
- Water Monitoring
- Pyranometer

inDAC Sensor Data Acquisition & Control Module

- Reveals performance and ROI of equipment including how heating, cooling, and ventilation systems impact comfort conditions within a building. Allows for accurately sizing HVAC systems by assessing how they perform.
- The inDAC system reads sensor data from sensors on 1-Wire networks, including pulse counters, and analog output from equipment like Heat Recovery Ventilators, Energy Recovery Ventilators, Fan Coil Units, etc. Monitor temperature, air flow, water/propane flow, humidity, air quality, and more.
- The inDAC works with the eMonitor Gateway to send information to the Internet.

inDAC Sensor Data Acquisition & Control Module cont.

inDAC Overview

- The inDAC is a microcontroller designed for monitoring and controlling building systems. The controller features a MODBUS RTU communication protocol for connection to a MODBUS enabled gateway device.
- Multiple inDAC units can be placed in series via MODBUS to expand analog and digital inputs/outputs for increased monitoring and control.

inDAC Applications

- Solar thermal system monitoring
- Ground source heat pump system monitoring
- Domestic hot water system monitoring
- ERV & HRV characterizations
- Rainwater collection systems

eMonitor Gateway

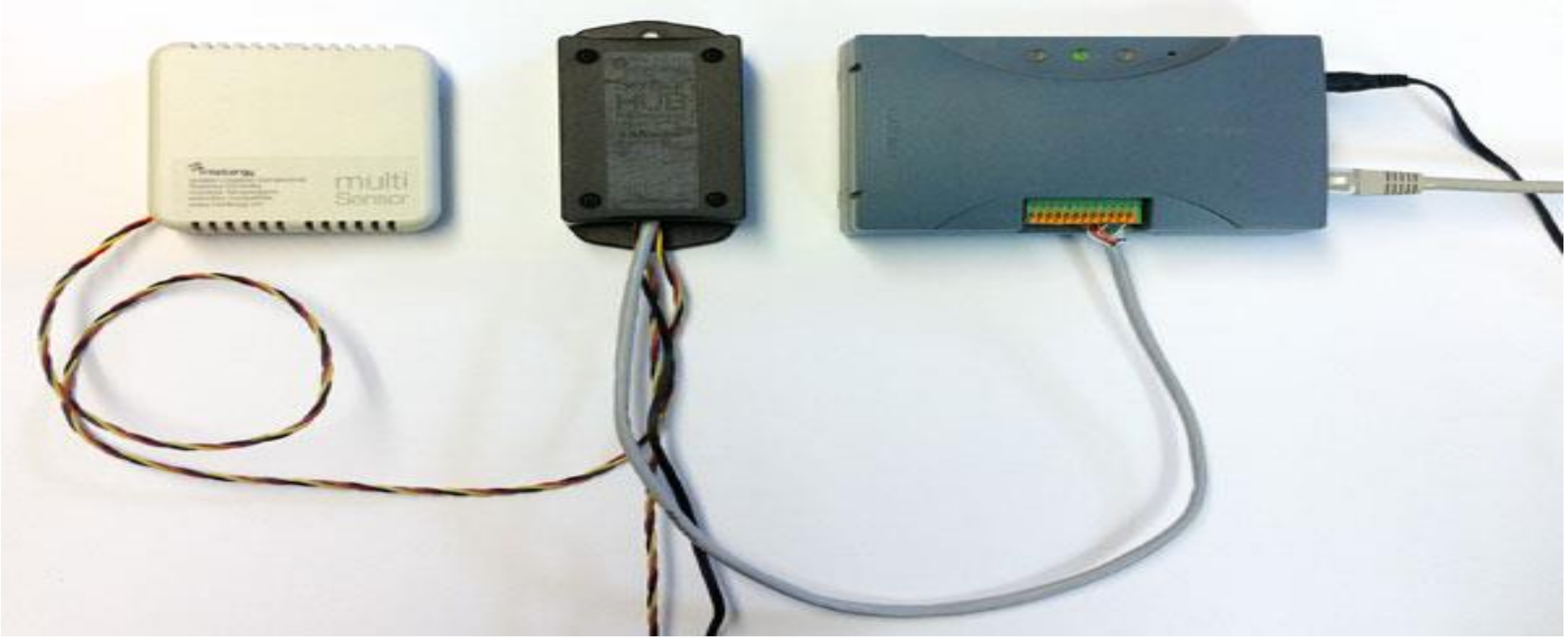
- The eMonitor Gateway requires an eMonitor to connect to the Internet and configure it properly.
- The sensors are connected to the PowerWise Sensor Hub, or the PowerWise inDAC, which connects in turn to the Gateway.
- The Gateway connects **wirelessly** or by **Ethernet** to the local network, and sends data to the Intellergy data servers, where it can be accessed in various ways.
- Add sensors and controls are added to the eMonitor during installation to analyze solar PV and hot water system health, water heater performance, A/C and heat pump efficiency, etc.

eMonitor Gateway cont.

eMonitor Gateway Installation

- A typical installation of an eMonitor Gateway with an Intellergy Sensor Hub and an Intellergy Multi Sensor is shown below.
- The Gateway comes configured for wireless connection to the local network. However, the Gateway shown is configured to use an Ethernet connection to the router. This is an option for installations in which the Gateway is too far from the router to connect wirelessly.

eMonitor Gateway Installation cont.



On the left is the Intellergy Multi Sensor. It's wired into the Intellergy Sensor Hub. Many sensors can be daisy-chained on a One-Wire Network, and connected to the Intellergy Sensor Hub. The Sensor Hub is in turn wired into the Gateway with standard cat 5 cable. This is shown for reference. Complete installation information and wiring diagrams comes with the equipment itself.

Circuit-Level Energy Monitoring

- The eMonitor provides an affordable solution for homeowners to monitor the energy use on every circuit of the home, giving them visibility of where energy is being used – and wasted – and the ability to take action.
- The eMonitor provides a unique combination of circuit- and appliance-level monitoring, continuous analytics and diagnostics, tailored recommendations, wide spectrum of safety, cost, and usage alerts, and easy-to-use web interface.

Circuit-Level Energy Monitoring cont.

Circuit-Level Energy Monitoring cont.

- The eMonitor's is the only energy monitor for monitoring all circuits in a home.
- The eMonitor provides detailed insight into a home’s energy usage, allowing for identifying when appliances aren't performing as they should.
- Learn where your cell phone chargers, coffee makers, and satellite receivers draw phantom power, costing money without the homeowner knowing it, and receive proactive alerts about your energy use.

eMonitor Features

- Home Energy Management
- Saving on your Energy Bill: End Phantom Power

Home Energy Management

- Proactive alerts tell you by email or text message if:
  - a circuit is on longer than it should be
  - the eMonitor can't connect to the internet
  - the estimate of an electric bill goes over a certain amount, set by the homeowner.

End Phantom Power Usage

- Phantom power users are also referred to as energy vampires.
- The eMonitor finds and pinpoints phantom/vampire loads.
- For the average homeowner that has up to 40 of these phantom devices, this feature will reduce energy usage by as much as $30-50/month.

inView Passive™ House Monitoring

- A powerful package of hardware and software designed specifically for monitoring Passive House buildings.
- Co-developed with Passive House Institute US (PHIUS) and Passive House and green building experts, inView Passive™ includes sensors, data acquisition and communication hardware, inServe™ data analytics and processing, and inView™ dashboard software.

inView Passive™ House Monitoring cont.

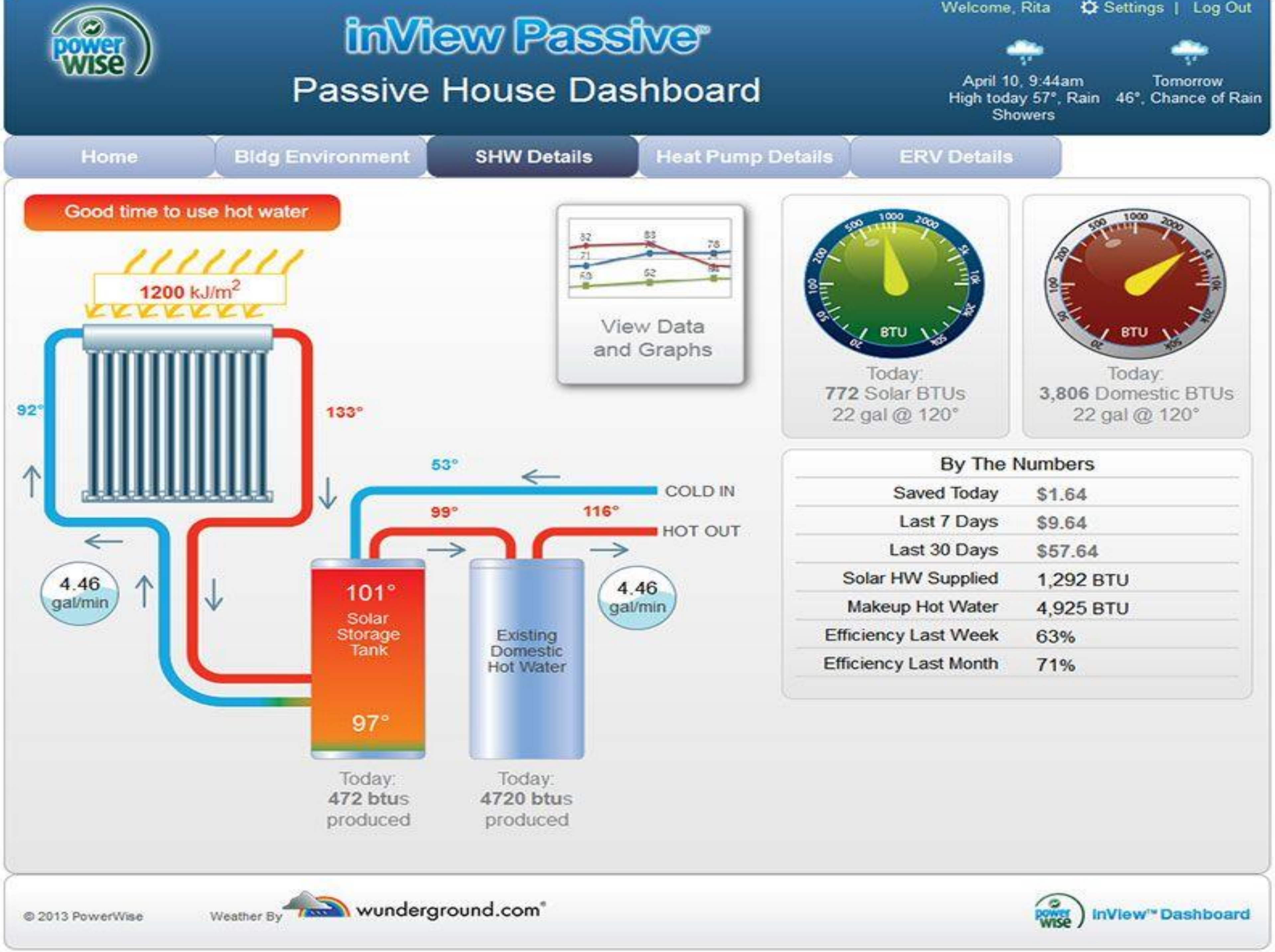
- Gain insight into performance, costs, and environmental conditions of entire buildings or individual HVAC and hot water systems.
- Visualize your solar hot water, ERV, HRV, and ground-source heat pumps with our detailed online dashboards.
- Know how these systems are running with real-time and historical readings. Plus, easily monitor circuit-level energy use, air quality, temperature, humidity, and more.

inView Basic Package

- eMonitor4-14 (2 mains + 12 circuits)
- inDAC™ (Data Acquisition Controller)
- 3 temperature sensors
- Relative humidity/temperature sensor
- VOC/relative humidity/temperature sensor
- Hardware enclosure
- inView Passive™ Passive House Dashboard
- Different hardware configurations are available to expand the monitoring capabilities.


inView Passive
Passive House Dashboard
Welcome, Rita
Settings | Log Out
April 10, 9:47am
High today 57°, Rain Showers
Tomorrow
48°, Chance of Snow
Humidity
100%
Temp
41°
38%
78°
0
500
1000
1500
2000
High
Medium
Low
AIR QUALITY
Watts
-5000
0
2500
5000
To Grid
Home
Last Mo
491 watts
Saved $25.55 this week
Green Power: 2061w
Grid Power: -1570w
5000
3750
1000
2500
0
Generated: 2061w
0w Wind
2061w Solar
Building Environment Details
Real-Time Electricity Details
Renewable Generation
112°
92°
Water is hot
74°
54°
42°
69°
1482 BTU Saved
emonitor Login
Export My Data
1700
N 18th St
Belfield Ave
Google
Map data ©2013 Google
Solar Hot Water Details
Heat Pump Details
ERV Details
My Location
© 2013 Intellergy, Inc.
Weather By wunderground.com
inView Dashboard


inView Passive
Passive House Dashboard
Welcome, Rita
Settings | Log Out
April 3, 1:24pm
High today 41°, Partly Cloudy
Tomorrow
52°, Partly Cloudy
Home
Bldg Environment
SHW Details
Heat Pump Details
ERV Details
Humidity
35%
Temp
38°
39°Avg
1 days
30%
68°
AIR QUALITY
Day
Week
Month
Data | Min | Max | Avg
Outside Temp | 26° | 57° | 39°
Inside Temp | 67° | 70° | 68°
Inside Relative Humidity | 26% | 33% | 30%
Indoor Air Quality | 1268 | 1268 | 1268
Day
Week
Month
Year
temperature
voc
rh
temperature vs. voc
temperature (null)
voc (ppm)
04/02 2PM
04/02 5PM
04/02 8PM
04/02 11PM
04/03 2AM
04/03 5AM
04/03 8AM
04/03 11AM
temperature
voc
rh
LVL2-Hall (°F)
LVL2-BedRm (°F)
LVL3-BedRm (°F)
LVL1-Hall (°F)
LVL1-Living (°F)
LVL2-BedRm (°F)
LVL3-Mech R (°F)
LVL1-BedRm (°F)
LVL3-Office (°F)
LVL2-WashRm (°F)
LVL3 - Mech (ppm)



Welcome, Rita
Settings | Log Out
power wise
inView Passive
Passive House Dashboard
April 10, 9:44am
High today 57°, Rain Showers
Tomorrow
46°, Chance of Rain
Home
Bldg Environment
SHW Details
Heat Pump Details
ERV Details
Good time to use hot water
1200 kJ/m2
92°
133°
53°
COLD IN
99°
116°
HOT OUT
4.46 gal/min
4.46 gal/min
101°
Solar Storage Tank
97°
Existing Domestic Hot Water
Today: 472 btus produced
Today: 4720 btus produced
View Data and Graphs
BTU
Today: 772 Solar BTUs 22 gal @ 120°
BTU
Today: 3,806 Domestic BTUs 22 gal @ 120°
By The Numbers
Saved Today $1.64
Last 7 Days $9.64
Last 30 Days $57.64
Solar HW Supplied 1,292 BTU
Makeup Hot Water 4,925 BTU
Efficiency Last Week 63%
Efficiency Last Month 71%
© 2013 PowerWise
Weather By wunderground.com
InView™ Dashboard

Welcome, Rita | Settings | Log Out

inView Passive

Passive House Dashboard

April 10, 9:46am
High today 57°, Rain Showers

Tomorrow
48°, Chance of Snow

Home | Bldg Environment | SHW Details | Heat Pump Details | ERV Details

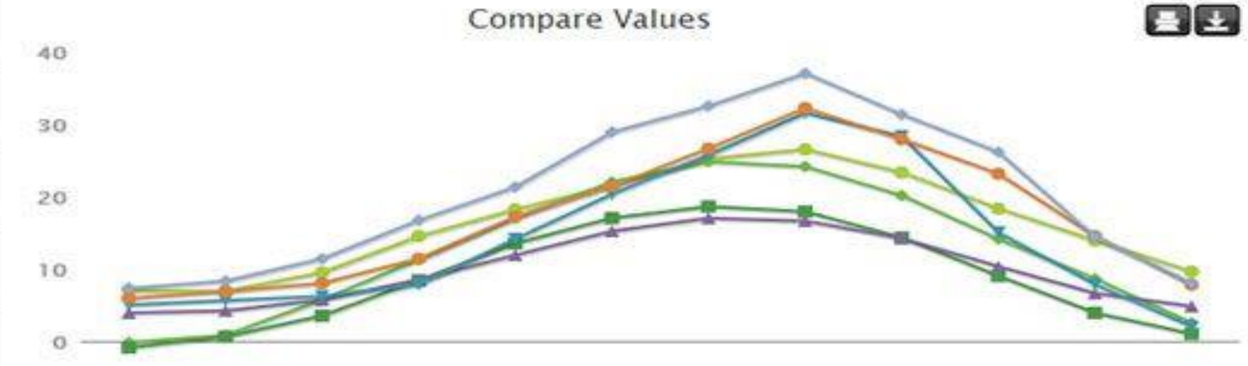
Data	Min	Max	Avg
Insolation	0w/m2	1180w/m2	630w/m2
Panel Temperature	-10°	147°	114°
Glycol Return	72°	118°	98°
Glycol Supply	70°	213°	162°
Glycol Flow	0	1.9gpm	1.4gpm
Cold Water In	49°	58°	54°
SHW Tank Bottom	62°	112°	98°
SHW Tank Top	72°	124°	118°
SHW to DHW	71°	122°	117°
DHW Out	112°	124°	118°
Water Flow	0	6.2gpm	2.4gpm

View Details

Day | Week | Month | Year

Export SHW Data

Temp
DHW BTU
Circ Pump
SHW
Irradiance



Temp
DHW BTU
Circ Pump
SHW
Irradiance

Welcome, Rita | Settings | Log Out

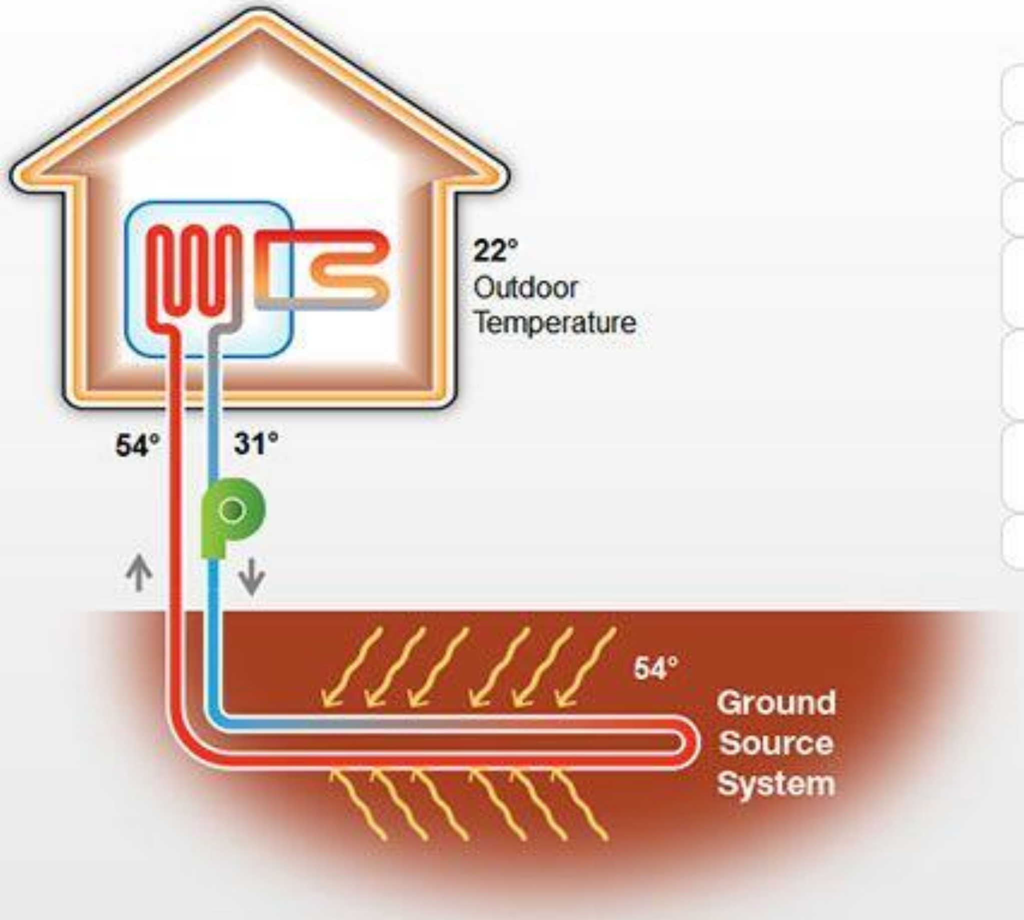
inView Passive™

Passive House Dashboard

April 10, 9:48am
High today 57°, Rain Showers

Tomorrow
48°, Chance of Snow

Home | Bldg Environment | SHW Details | **Heat Pump Details** | ERV Details



Data	Min	Max	Avg
Outside Temp	-7	41	18
Ground Temp	52	56	54
Ground Source Supply	53	56	54
Ground Source Return	28	45	36
Ground Loop Flow	0.4gpm	1.2gpm	0 0.8gpm
Indoor Temp	62	74	68

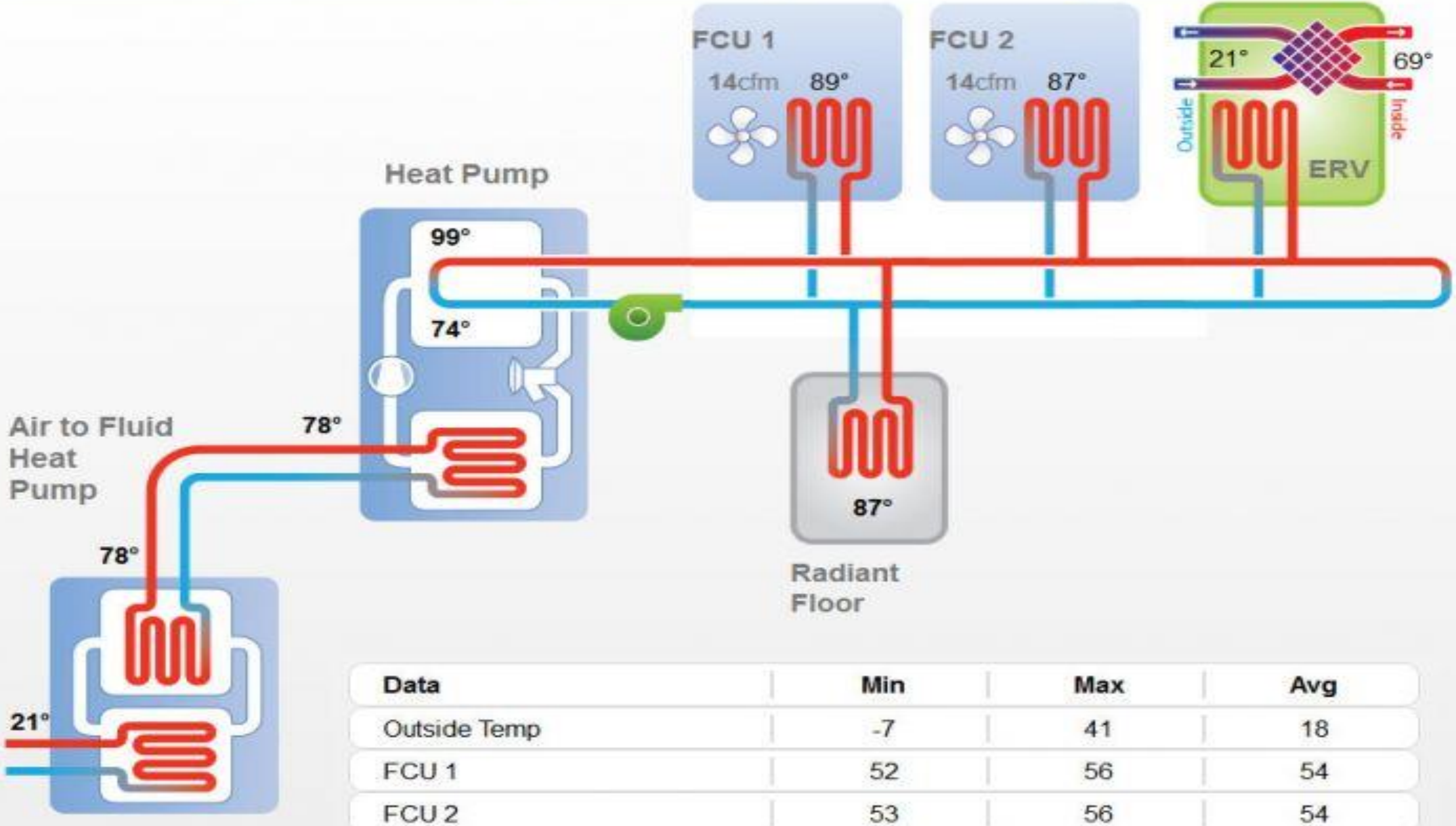
View Distribution Details

inView Passive®

Passive House Dashboard

April 10, 9:51am
High today 57°, Rain Showers

Tomorrow
48°, Chance of Snow



Data	Min	Max	Avg
Outside Temp	-7	41	18
FCU 1	52	56	54
FCU 2	53	56	54
ERV Outside	28	45	36
Radiant Slab Temp	67	98	94
Indoor Temp	62	74	68

Welcome, Rita   Settings | Log Out

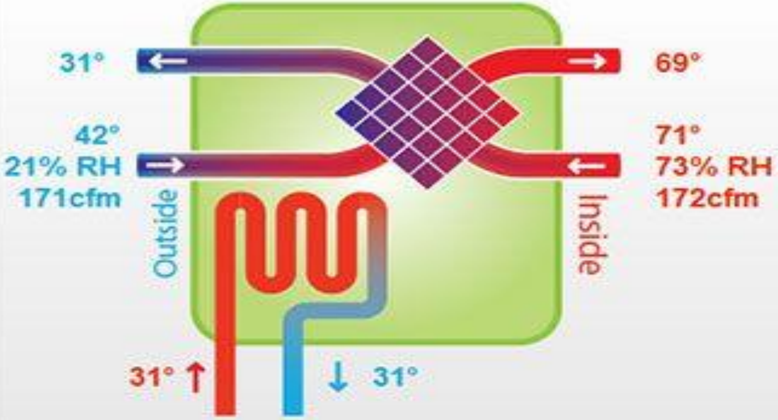
inView Passive

Passive House Dashboard

April 10, 9:55am
High today 57°, Rain Showers

Tomorrow
48°, Chance of Snow

Home | Bldg Environment | SHW Details | Heat Pump Details | ERV Details



Data	Min	Max	Avg
Outside Temp	-7	41	22
Outside Relative Humidity	24%	95%	46%
Inside Temp	62	78	69
Inside Relative Humidity	42%	98%	56%
Supply Flow	21cfm	342cfm	173cfm
Return Flow	21cfm	340cfm	172cfm

Day | Week | Month | Year

Temp
DHW BTU
Circ Pump
SHW
Irradiance

Temp
DHW BTU
Circ Pump
SHW
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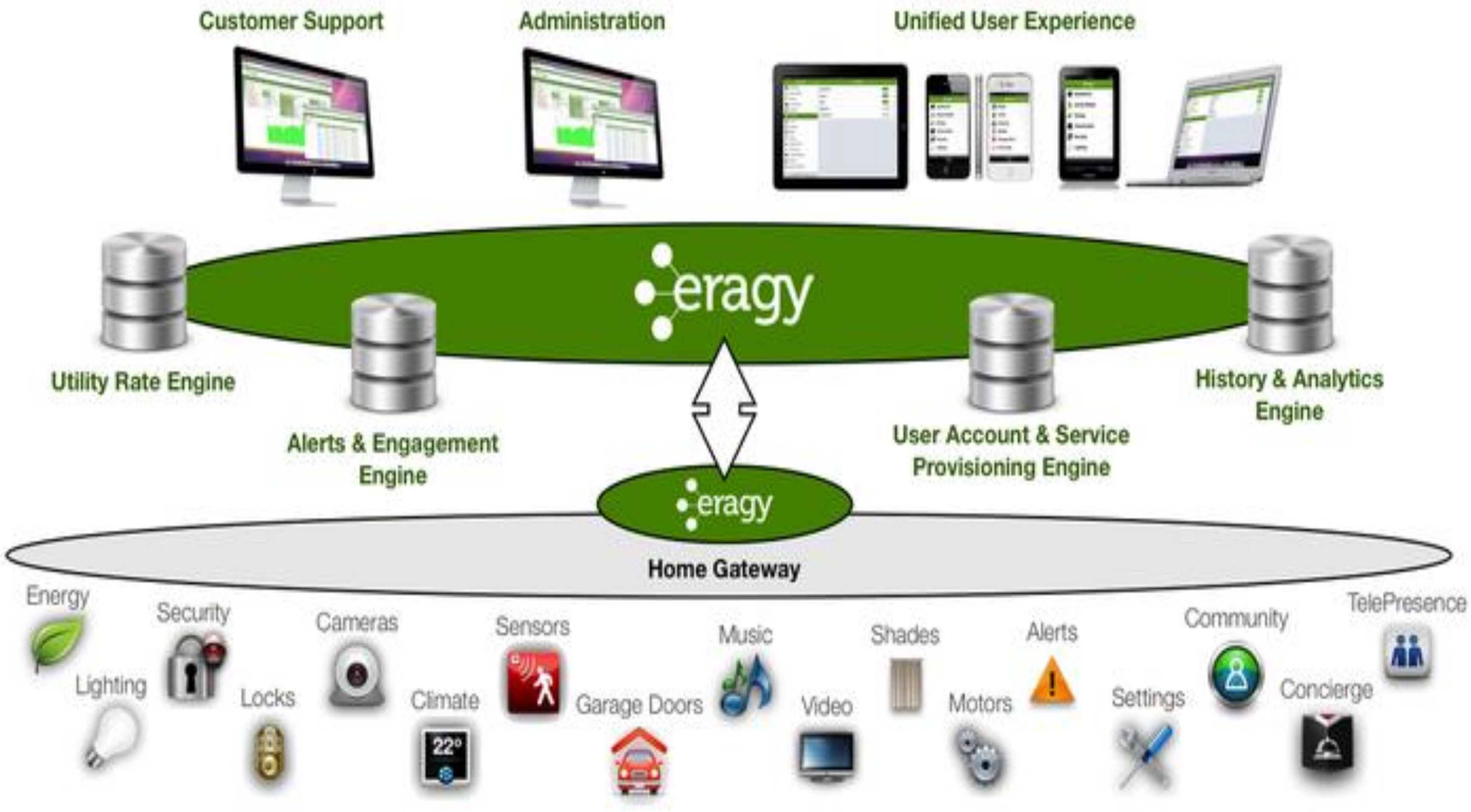
Eragy Orbit & Control4

- Eragy Orbit and Control4 and their connected home platforms work in tandem with a home gateway which enables homeowners and businessmen to monitor and control their homes and businesses from anywhere using their cloud-based mobile platform.
- Orbit and Control4 users can monitor and control their energy, cameras, lighting, thermostats, door locks and more -- all from their mobile device!

Eragy & Control4 Solution



High Efficiency Appliances

- The Consortium of Energy Efficiency publishes a yearly list of the most efficient appliances (tier 3) for residential and business applications which substantially exceed federal standards.
- The top performing manufacturers will be invited to contribute and showcase their appliances in our model home (for demonstration of passive house technology).

Energy Star Appliances

- Appliances account for nearly 20% of the average household's energy use.
- A comprehensive package of ENERGY STAR qualified appliances can save up to $80 a year in energy costs compared to standard appliances.

Beautiful Concrete Floor Designs

- Can be developed for a variety of colors and designs for concrete floors.
- Providing unmatched quality and craftsmanship similar in decorative looks to polished marble or granite.
- Can be designed and applied to fit any homeowner budget.
- Ideal for use with radiant heating and cooling via Quad-Deck technology.




Concrete Dying & Polishing

- Conducted after the concrete is poured and cured, and bearing walls are in place.
- An extremely flat surface is required for best finish.
- Sub-contractor fees run from $4-5/sf. (primarily labor)

Concrete Countertops

- Relatively low-cost substitute vs. corian and granite
- Much higher quality than laminate
- Materials are low-cost
- Concrete coloring and design allow for very attractive floors and countertops and very competitive pricing
- Sinks can be constructed with concrete and integrated with kitchen and bathroom countertops
- Drop-in and undermount sinks

Pour in Place with PVC Edging

- There are significant economic advantages for pouring in place using PVC edging forms that also serve as guides for screeting to provide a level and flat surface.
- This eliminates grinding, moving, and transporting heavy concrete countertops.
- The following photos of pour in place concrete countertops use a variety of edging form styles, coloring, and dyes from Z Counterform Concrete Countertop Solutions .


MOON
MOON
BE NICE... OR GO AWAY


Checker/Chess Board Dyed into Concrete Countertop

Residential Energy Tax Credits

- 30% for geothermal heat pump systems
- 30% for solar power systems
- 30% for wind power systems

Energy Efficiency Mortgages

- More and more lenders provide so-called "Energy Efficient Mortgages" (EEM).
- These mortgages recognize the fact that highly energy efficient homes cost less to operate.
- This in effect increases a borrower's income - money in your pocket or to qualify for higher mortgage amounts/shorter terms.

How an Energy Efficient Home more than Pays for Itself

- Borrower finances 100% of energy improvements - 6.0% 30-year mortgage	Standard Mortgage	EEM
Energy Improvement Costs	-	$6,000
Appraisal Value	$200,000	$206,000
Down Payment	$20,000	$20,000
Mortgage Amount	$180,000	$186,000
P & I	$1,079	$1,115
Monthly Energy Savings	-	**-$80**
Total Monthly Payments	**$1,079**	**$1,035**

Passive House Savings

- This means that after paying for the additional cost of Quad-Lock ICF there is an additional savings of $44/month, $528/year, and more with rising energy costs...
- Savings would be even greater with integration of geothermal heat pump, radiant heating, cooling, hot water heating systems, efficient windows and doors, and high efficient appliances via passive house design

Prequalifying via EEM Lender

Steps:

- Pre-qualify with an EEM Lender (see Dept. of Energy Listing)
- Evaluation of home's energy efficiency (e.g., inspection by a professional energy rater, see RESnet Rating Providers)

Builder Incentives

- A credit of $2,000 is available to home builders who build high-efficiency homes (including both site-built and manufactured homes).
- Qualifying homes must be designed so that heating and cooling energy used will be 50% less than a home that meets the standards of the 2006 International Energy Conservation.
- In addition, a $1,000 credit is available to manufactured home producers producing models that save 30% or that qualify for the federal Energy Star Homes program.
- **These credits are available for buildings or systems placed in service from January 1, 2006, through December 31, 2013 (**IRS Form 8908).

Strategic Design & Integrated HVAC System

- Southern exposure allows for maximizing solar gain in winter through strategic glazing in conjunction with radiant floor heating and cooling.
- Living space can be more than tripled by converting crawl space and attic space into value added living space while reducing labor costs by as much as 50% while increasing quality and affordability.
- Peak heating and cooling loads can be reduced by over 95% through use of thermal mass for ICF technology to provide envelopes with 0 ACH@50, R-50 insulation in exterior walls, and R-60 insulation in the roof/vaulted ceiling.
- Integration of solar thermal, water to water GSHP, ground to air heat exchanger, and 96% efficient ERV provide unprecedented energy efficiencies.

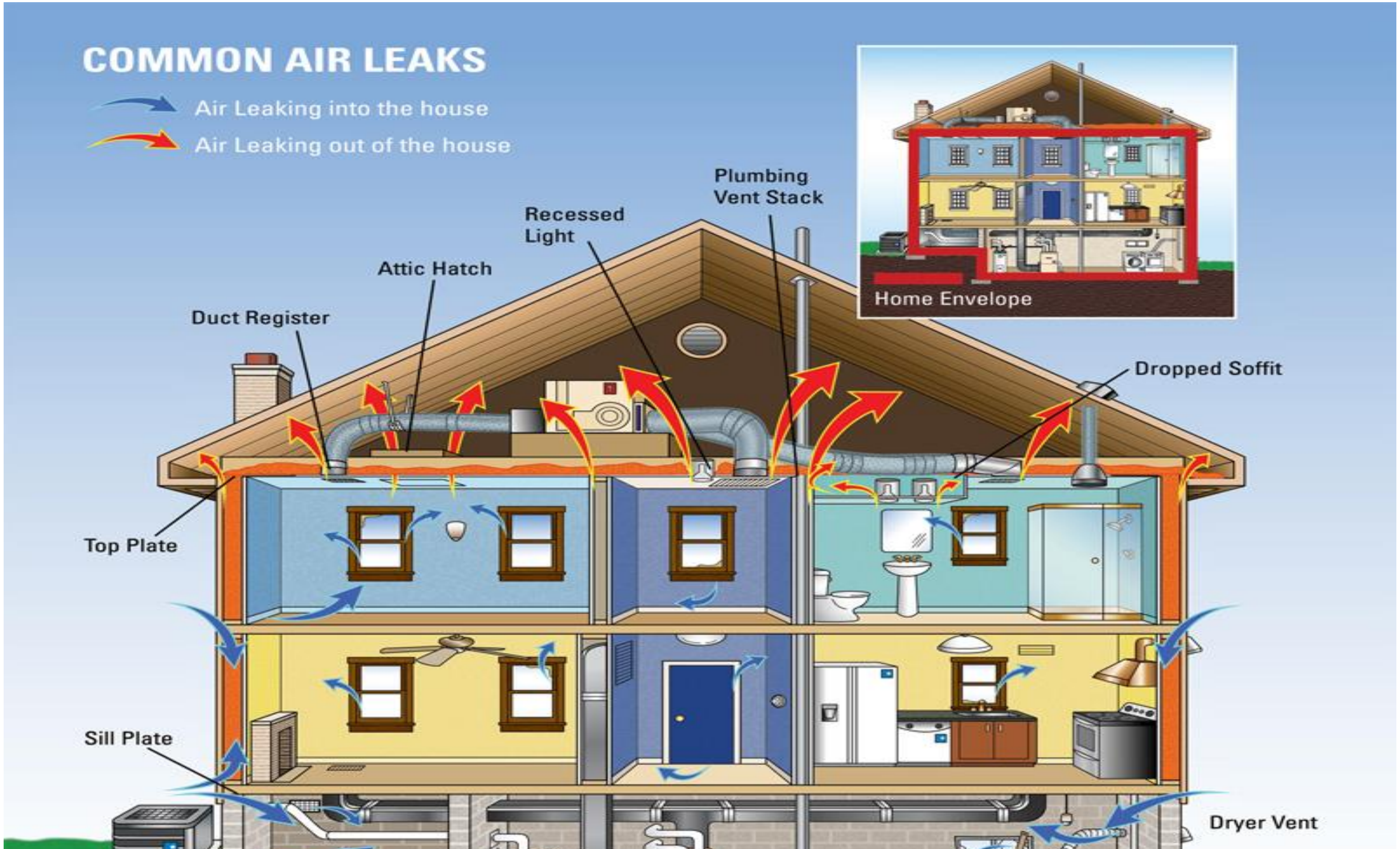
Idaho Home Sales

- In 2013, Idaho property values have increased by 30% over the previous year.
- New homes sales in Boise, ID have dramatically increased, many are currently selling before construction is complete.

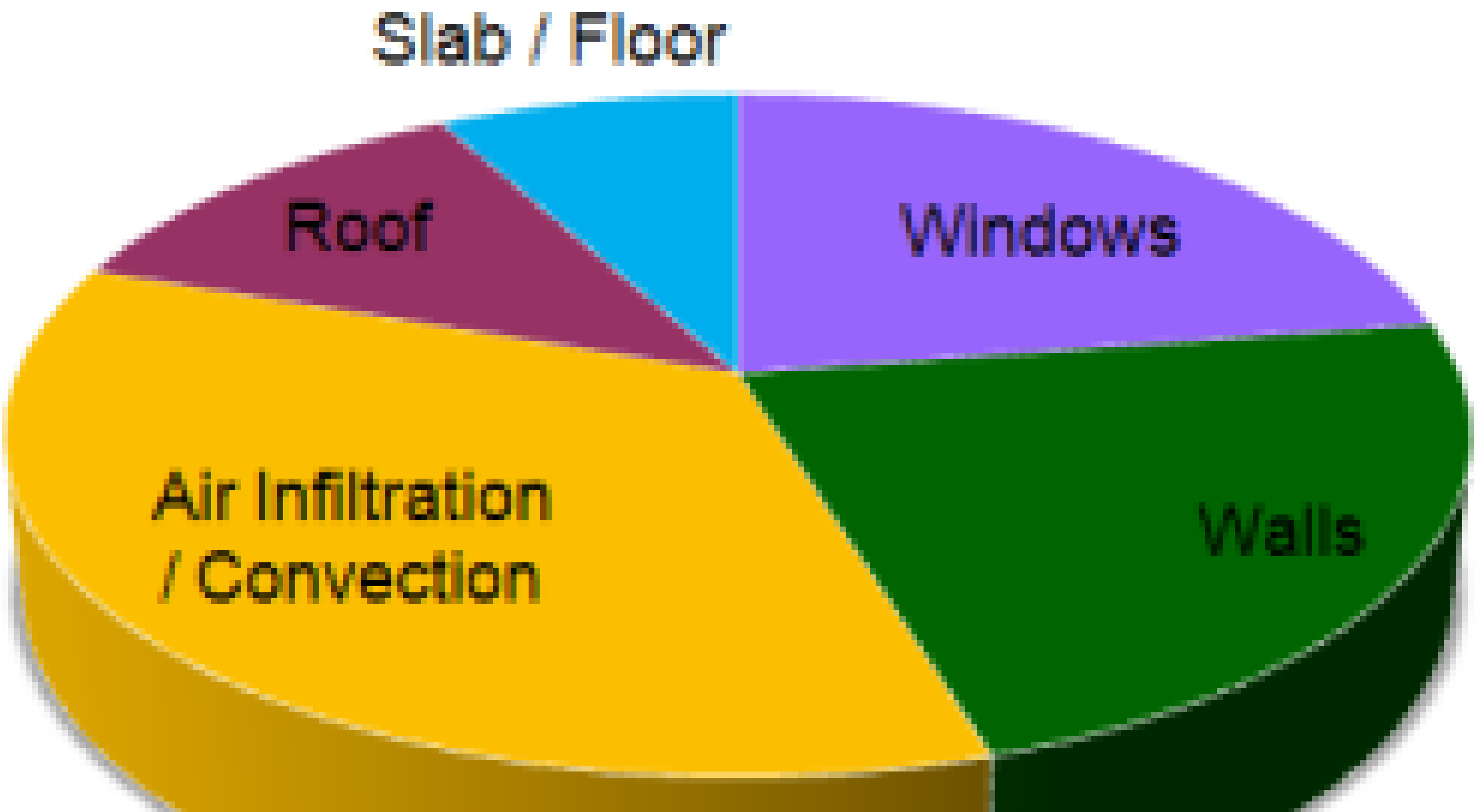
Passive House Model Home Design

- Roof overhangs, window size and placement, and overall home shape have a major impact on achieving net-zero homes.
- Focus will be on managing solar gain.
- A strategic portion of the roof will face south and west.
- Placement of porches, garages, trees, and nearby buildings will be included in strategic plans for passive house design.

Avoiding Air-Leakage



Sources of Energy Loss in a Wood Frame Building



ICF, Passive Windows & Entry Doors will Minimize Air-leakage

- ICFs will ensure airtight walls and ceilings.
- Passive windows and doors will be utilized.
- Kitchen and bathrooms will be provided with adequate ventilation while maintaining energy efficiency.
  Triple glazed windows with minimal air-leakage and well insulated or external doors in covered/protected entry ways will be utilized.
- Passive gain of incoming solar heat through strategically placed windows will recoup close to 40% of heat losses.

Ranch Style Floor Plan with Full Basement & Loft

- A full basement provides the most cost effective use of building materials and labor resources.
- When a sloped lot is utilized, a walk-out basement is ideal.
- Using Quad-Lock and Quad-Deck ICF technology also allows for efficient use of loft space as a relatively inexpensive 2nd story.
- This almost triples floor space for the average home or office building.

Vaulted Ceiling & Loft

- Vaulted ceilings will be constructed using Quad-Deck and milled/sized logs to reduce shoring and enhance beauty for the upstairs loft/bonus room and venting/utility allies along all four sides of the structure.
- Eaves will be extended 4-5’ beyond walls using a 4-5” cement slab insulated with 5” of 4’ x 8’ sheets of dense foam glued to the concrete roof.
- The foam will be covered with OMB, anchored to the cement roof, and covered with a roofing membrane.

Boise Lodge Logs

- Milled logs from Boise Lodge Logs will be utilized to provide accurate sizing and uniform circular block-outs for ICF.
- Logs are cured using a 6-8 week solar energy process to minimize cracking and warping.
- Logs will come pre-drilled for anchoring to Quad-lock walls to provide shoring during pouring of floors and roof ICF structures.

Heat Pump, ERV & Radiant System Control

- Teckmar's tN2 406 House heat pump control and teckmarNet Thermostat 557 zoning may be used for the radiant heating, cooling, hot water, and coil backup system integrated with the ERV.
- The teckmar controller comes with a dew point reset and humidity regulator for using radiant cooling in conjunction with a hot/cold coil that will be integrated with the ERV.
- Due to the 200-300 CFM air flow limitation of the ERV, two ERV systems may eventually be employed to accommodate a basement, main floor and 2nd story.

Rectangular Shape & Solar Orientation

- Allows for maximizing southern exposure and limiting northern exposure for passive solar homes built in the northern hemisphere.
- The rectangular shape also limits the size of the envelope which enhances energy efficiency.
- The majority of the windows for the PHMH will be placed on the southern side of the structure and treated to maximize solar gain.

Front Facing Garage

- The garage could be placed where the bedrooms are and then move the bedrooms upstairs to the 2nd story/loft over the garage.
- This would allow for reducing the length of the structure for accommodating smaller lots.
- A full basement could also be added via ICF technology and will possibly be showcased at the PHMH project.

Envelope Size

- The total square footage of living space for the above floor plan can be modified simply by proportionately reducing dimensions, from 1700-3200 sf. on the main floor.
- Full basements, insulated food storage, and lofts/2^{nd} stories can be added to this design, providing additional bedrooms, bathrooms, family room, a home theatre, home office, or basement living quarters for in-laws, etc.
- The great room is optional.

Hayden Homes

- Very small lots in South Hill Subdivision
- Homes ranging from $77/sf to $103/sf:
  - **Parkland** - 1889 sf plus 365 sf optional bonus room, 3-4 bedrooms, 2.5 baths, 2-3 car garage - $195,000
  - **Waterville** - 2 story – 3195 sf, 4-6 bedrooms, 2.5-34.5 baths, 3 car garage - $245,000

Target Home Price - $75-100/sf in the Greater Boise Area

- Need to work with developer or establish own development to keep lot prices down and energy efficient homes competitive via EEM and tax credits.
- Medium price of homes available on 0.33 to 0.5 acre lots should be in the $250,000-350,000 range
  - 2,000-4000 sf with finished basement or 2^{nd} story loft
  - 3-6 bedrooms, 2 family rooms, food storage, home office and/or home theatre
  - 2.5-4 baths
  - 2-3 car oversized garage

Reducing Material & Labor Costs

- Training in ICF construction, decorative concrete flooring, and concrete countertops will be conducted during the building of the PHMH.
- This will allow experienced ICF and decorative concrete crews to substantially reduce labor costs.
- Labor intensive sheetrock, taping, mudding, sanding, texturing and painting will be replaced with attractive ceiling decking and paneling using pre-treated pine or fir tongue and groove 1x6 or 1x8 products.

Industry Partners, Training & Referrals

- Industry partners will contribute materials and local contractors and subcontractors will contribute labor for building of the PHMH.
- In exchange for contributing labor, contractors and subcontractors will receive free training on materials, equipment, and techniques during the building of the PHMH.
- Contractors and subcontractors will be provided with contract work resulting from showcasing the PHMH. Once they become certified in ICF and other products/equipment, they will also receive referrals from product manufacturers.

Geothermal Heat Pump System

- Reducing the energy load by 90% may allow for using as little as a 2.5 ton variable capacity geothermal heat pump for over 4,000 sf.
- The labor intensive process of excavation and burying field loops will be minimized by laying horizontal loops around footings with monitoring and hydration systems in order to keep the groundwater source fully charged.
- The field loops and geothermal heat pump system will be integrated with radiant cooling, heating, hot water, and ERVs.

Monitoring Heat Capacity & Hydration Systems

- Dry soil has a heat capacity of about 0.20 BTU/lb./°F of temperature change—only one-fifth the heat capacity of water.
- Moist soils have better heat capacities of about 0.23–0.25 BTU/lb./°F.
- Hence, accurate monitoring of heat capacity and routine use of hydration systems can increase efficiency of field loops and geothermal heat pump systems by up to five fold.

Adding Value via Reduction of Energy Expenses

- Tax credits, the savings in monthly energy costs, and sweat equity will allow for homeowners to upgrade energy efficiency, e.g., passive windows and doors and the purchasing of more home for new construction.
- Additional upgrades could include:
  - photovoltaic panels for achieving net-zero homes
  - smart home technology including home security and home theatre
  - energy efficient appliances

Developing Net Zero Community

- Brooklyn NY and Issaquah WA (http://www.z-home.org/) have both successfully developed Passive House and Net Zero communities.
- Both of these communities have sold out.
- In order to insure that we are competitive and successful with our PHMH, we will find investors who are willing to develop such a community in Boise, ID.

zHome Condos Sold Out

- zHome is a revolutionary, 10-unit townhome development that uses smart design and cutting edge technologies to radically reduce its environmental impacts.
- zHome will prove that homes that use zero net energy and 60% less water, emit net zero carbon emissions, have clean indoor air and use only low-toxicity materials are possible and scalable to mainstream home production.

Cost is only 10-15% more than building to current codes

- According to Katrin Klingenberg, executive director of the Passive House Institute U.S. (PHIUS), her office receives at least one request each week from a developer seeking Passive House precertification. And the projects aren't only single-family homes; affordable housing, commercial and school projects also are in the works.
- "The growth since we began certifying Passive Houses in the U.S. has been exponential," Klingenberg said. "The beauty of the Passive House method is the simplicity of the system. As you eliminate the mechanical systems, the cost is only 10-15% more than building to current codes."